TWENTIETH CENTURY AGRICULTURAL SCIENCE

DISCOVERY
USE
PRESERVATION

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Edited By:

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INTRODUCTION

The science of agriculture in the New World first attracted the interest of the wealthy and the well-born. In Colonial America, agricultural experiments and their resulting communications were primarily the activity of the small group of articulate gentleman farmers and planters. These agriculturalists transmitted their findings to each other through correspondence, books, treatises, journals, the press, and by participation in the meetings of agricultural societies such as the Philadelphia Society for Promoting Agriculture and the South Carolina Society for Promoting and Improving Agriculture. As the eighteenth century drew to a close, scientific advancement in agriculture included Eli Whitney's invention of the cotton gin in 1793, Charles Newbold's patent for the first cast iron plow in 1797, and George Washington's recommendation for the creation of a national board of agriculture.

When the Department of Agriculture was finally established in 1862, some 66 years after Washington's recommendation, the first Commissioner of Agriculture, Isaac Newton, was directed "to acquire and preserve . . . all information concerning agriculture which he (could) obtain by means of books and correspondence and by practical and scientific experiments." In 1887, increased impetus to agricultural research came with the passage of the Hatch Act which provided for the establishment of experiment stations in connection with land-grant colleges. Federal funds were allocated to each state "to promote scientific investigations" and to publish the results.

Today, almost one hundred years later, the United States is providing more food and agricultural assistance to developing nations than any other country in the world. As a result of the breakthroughs and improvements in science and technology occurring in the twentieth century, American agriculture is able to produce the necessary food and fiber for domestic consumption and foreign export. The relationship between the world's food supply and America's food supply clearly underlines the importance of agricultural science, productive farmers, and the overall food system. The potential consequences, however, of population explosion in developing countries, natural and man-made disasters, disease, food shortages and famine remain as major challenges for today's world leaders.

How did the United States become the richest food producing nation in the world? How will the food producing nations establish priorities and share scientific efforts and knowledge? With these questions in mind, the idea for a Symposium on Twentieth Century Agricultural Science was conceived in the fall of 1980 and, on October 29, 1981, Alan Fusonie and Leila Moran were designated as the official coordinators. It was hoped that a forum could be developed for discussing the accomplishments, trends, and future developments in agricultural

research in this century, as well as for focusing on the interaction between scientists, information specialists, writers, librarians, and many others in the collection, dissemination, and utilization of agricultural information. Previous successful published symposiums have included: Agricultural Literature--Proud Heritage, Future Promise; Heritage of Maryland Agriculture, 1776-1976; International Agricultural Librarianship--Continuity and Change; Animal Health and Disease Data Bases. Other Associate publications include the following: Abraham Lincoln--His Legacy to American Agriculture (1972); The National Agricultural Library--A Chronology (1974); The Land-Grant Colleges--A Selective Historical Bibliography and Legislative Chronology (1983).

As the program for the Symposium on Twentieth Century Agricultural Science became more formalized, three groups agreed to act as sponsors: the National Agricultural Library; the Associates of the National Agricultural Library, Inc.; the Agricultural History Society. In addition, one of the evening events, a wine and cheese get-together, would be sponsored by the American Association of Nurserymen, Inc. The Symposium, which was planned for three days--October 20 to 22, 1982--turned out to be both a stimulating and a successful meeting that brought together over twenty-three speakers from various disciplines. The final day was a series of practical mini-workshops developed by Charles Gilreath and Wallace Olsen focusing on agricultural information, cooperation, and libraries. Because of the interdisciplinary nature of the Symposium papers, the diverse styles of references were in some instances left as submitted since they reflected the intent and integrity of the originator. The texts of all papers, however, have been revised to some extent by the editors.

There were many supportive hands involved in the ultimate success of the Symposium including the following: Leila Moran, co-coordinator; Marilyn Jacobs, arrangements with National 4-H Center; Gene Farkas, publicity. Appreciation is also extended to Charlotte Trevieso and Bonnie Callan of the Extension Service, to Stan Prochaska, Governmental and Public Affairs, and to Joe Judy, David Hoyt, and Bill Longnecker, of the NAL staff. Support typists included Mary Silva, Shirley Suprenant, and Carolyn Burke. Finally, a special debt of gratitude is extended to all of the registrants and speakers for providing splendid interactions and meaningful discussions.

ALAN E. FUSONIE
DONNA JEAN FUSONIE
Editors

WELCOME

Today, agriculture in the United States and other leading food producing nations is more specialized, more productive, and more sophisticated. In particular, during the last half of the 20th century, the success of United States food and agriculture has been based upon the increased application of improved science and technology.

As the Director of the largest agricultural library in the free world, I am made aware on a daily basis of the vital relationship between the continued growth, development and progress in the agricultural sciences and the process of acquiring, preserving and making available the recorded knowledge in agricultural and the allied sciences. NAL handles a heavy volume of inter-library loans, photocopy requests, data base search requests from all over the world. In promoting a more efficient and effective program for collection, processing, managing and dissemination, NAL is aggressively increasing its utilization and integration of the most advanced computers and other communication technologies.

We live in an "information age" and critical to man's survival today and in century three is the continued sharing of scientific knowledge at the local, national, and international levels. We come together here at the beautiful 4-H Center in the spirit of dialogue, discussions, interpretation and friendship. On behalf of the Secretary of Agriculture, John Block, the staff of the National Agricultural Library, the Associates of the National Agricultural Library, the Agricultural History Society, I welcome you and hope that your brief stay with us will prove to be a productive, profitable, and pleasant experience.

DR. RICHARD A. FARLEY

Director
National Agricultural Library
U. S. Department of Agriculture

IMPACT OF INFORMATION ON AGRICULTURAL RESEARCH

by

ORVILLE G. BENTLEY

It is a pleasure to be with you this morning and to take part in your "Twentieth Century Agricultural Science Symposium." When you issued your kind invitation asking me to speak today, I was dean of the College of Agriculture at the University of Illinois. Now, only a very brief time later, I find myself designated by the President to serve as Assistant Secretary of Agriculture for the Science and Education agencies, pending confirmation when Congress reconvenes in November.

I'm sure you will understand that I am still very much in the "shake-down" period of my tenure--"digging in" to get a better understanding of agricultural research and educational programs from a cabinet officer's viewpoint. And, of course, I am involved in the host of details necessary for getting settled into a new home and a new position.

From either perspective--that of a university dean, or that of an assistant secretary--your subject, "The Utility of Information in Agricultural Research, Its Economic Impact, and The Role of the Communications Media," is of vital concern. This is an area certain to see exciting innovations and undreamed of developments in the years ahead.

Men and women on the electronics frontier befriended the computer before most of us found the courage to touch a keyboard and began putting it to work in daily lives across our country. They have given us a glimpse into the computer-and-communications culture of the future...a future that is arriving with mind-boggling speed...a speed that says, "the future is NOW!"

During the time allotted to me today, I will first briefly describe where we are now in this rapid-growth era in communicating information to our constituencies--our progress and some of the hurdles we are encountering as we move ahead. Then I will share with you my opinions on where we are going--perhaps what we can look for in agricultural communications by 1990 and beyond.

The mission that guides our Science and Education agencies is basically the same as it has been for many years. It is to help develop science and technology in support of the Department's major goal. That goal, simply stated, it to expand production of food, fiber, and forest products in order to meet domestic and export needs at reasonable prices, while maintaining our natural resources for future production.

We are fortunate to have a Secretary of Agriculture in this Administration who has consistently supported agricultural research--both in speech and in action. Despite increased fiscal constraints and increased competition for each research dollar in the Federal budget, the Agricultural Research Service has fared relatively well as compared with other non-defense agencies.

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"Even with overall budget reductions, we have provided for increases in a few high priority areas," Secretary Block said when appearing before a Senate budget committee hearing. "We continue to regard agricultural research as a very high priority," he said.

I feel certain that this confidence expressed in agricultural research will pay dividends in the long-term picture just as the Administration is confident that the President's program for economic recovery will have long-term gains. There are already signs that President Reagan's program is beginning to show results. The inflation rate is down, making all Americans better off. Our dollars can buy more when inflation isn't cutting the value of the dollar 12 to 13 cents a year, as it did in 1979 and 1980. And lower taxes are adding more purchasing power for American families. Meanwhile, personal income and personal savings are up and we see persistent signs of economic growth for the first time since the late 1970's.

In support of the Department's goal for expanded production of food, fiber, and forest products to meet the needs of the future, the Agricultural Research Service (ARS) operates as the Department's own research unit. ARS provides leadership in conducting research on broad regional and national problems, in support of Federal action and regulatory agencies, and in international programs. Our scientists also provide talent for meeting national emergencies, and they are available as a scientific resource to the Executive Branch and Congress.

The Extension Service has long been recognized as the educational arm of the Department. For much of this century the Cooperative Extension Service has been the major informal educational system serving rural people. Now, leaders in both research and extension, as well as State universities and State experiment station directors, realize the need to adopt--and adapt to--new modes of communication to respond to changing needs and increasingly plural audiences.

The Agriculture and Food Act of 1981 declares it is the policy of Congress to encourage cooperation and coordination among agricultural libraries and information units. The Act calls on us to see that informational and library needs related to agricultural research and education are effectively planned for, coordinated, and evaluated. Agricultural libraries of colleges and universities, along with Department of Agriculture libraries and their allied information gathering and disseminating units, will work closely with private industry and other research libraries.

We must provide access for all colleges and universities and Department of Agriculture personnel to literature and information on the food and agricultural sciences. Programs for training in utilization of information pertaining to these sciences will be established and strengthened. This will include research grants for librarians, information scientists, and agricultural scientists. At the same time, USDA will establish mutually valuable working relationships with international and foreign information data programs.

Nowhere is a timely exchange of information more important than in USDA's Cooperative State Research Service (CSRS). Right now CSRS is working toward implementing an exchange of research material and other information through the use of CRIS--a Current Research Information System now in place. The states are getting their equipment installed and they are training personnel. In the very near future CSRS will be benefiting from a two-way system of electronic communication with directors of state experiment stations, 1890 colleges and the Tuskegee Institute, forestry schools, and schools of veterinary medicine.

CRIS is only one of the computer-based systems that has been developed by corporations, universities, associations as well as by local, state, and Federal governments as the need for improved information support has emerged in the agricultural community. I would like to mention just a few of the others now in use.

o There is AGNET--"Agricultural Network," a time-sharing information delivery system that provides assistance in problem solving questions about agricultural management. The network tracks market conditions and trends very much like an electronic mail service. In serving users in more than 40 states, AGNET offers programs which can provide information and a calculating capability in such areas as livestock and crop production, grain handling, marketing and finance, and home economics.

o Then, AGRICOLA--USDA's National Agricultural Library, the largest library of its kind in the world, provides comprehensive access to information on published literature and on-going research in agriculture through two information retrieval systems--CRIS and AGRICOLA. The AGRICOLA system contains world-wide coverage of published books, serial titles, and journal articles on agriculture and allied subjects.

In addition to bibliographic clearance citations of published literature, the system offers information through several specialized subfiles. An estimated 60 to 75 thousand 4-H and State extension popular publications are being listed in AGRICOLA. The project is intended to reduce costly duplication by both Federal and State governments.

o AGRISOURCE--Developed by the Computer Corporation of America in conjunction with the Extension Service, AGRISOURCE can provide users with access to geographically dispersed and heterogeneous information systems. We estimate there are presently more than 1,700 computerized data bases available for public use. Each of these data bases is accessible on its own computer host, using that system's protocol and language. Research has shown that it is unlikely to find users literate in more than six or seven different access languages and protocols. The problem is obvious. Something must be done to simplify access to these rapidly proliferating electronic information resources.

AGRISOURCE is an interface or a link between the users and the information resources. It can, through a user-friendly dialog, determine what the user's information needs may be. Then it could advise the user of the information resources that are available for that kind of information. When the user has made a choice, AGRISOURCE could make direct contact with the host computer, rephrasing the user's request in the appropriate computer language, and retrieve the information for the user. The concept has been developed on a limited basis so far, but we believe it could be applied throughout the USDA and can be useful to members of the agricultural community everywhere. Its development ought to be not only Department-wide but also carried out jointly with members of the private sector.

o CHASE ECONOMETRICS--A subsidiary of Chase Manhattan Bank, offering access to information in the areas of industrial economics, energy, minerals, international economics, United States economics, and agriculture. Data on agribusiness provides coverage at the international, regional, and state-wide levels.

o CMN--Which stands for Computerized Management Network, was developed by the Virginia Polytechnic Institute and State University as a national information system for use by State Extension Services. Designed for use by non-computer oriented persons, the system is currently accessed by more than 500 users in 44 states and Canada.

o EMA--was developed by the Electronic Marketing Association, Inc., of Christiansburg, Virginia, which first offered its computerized auction system for cattle and lambs in 1980.

o ESTEL--The Extension Service Telecommunications System is the University of Maryland's Cooperative Extension Service program which offers a videotext information service, ESTEL, to area farmers. Although this system is not yet fully operational, a pilot demonstration project to potential users in Somerset County offers promise as a model for other states. ESTEL originates from a microcomputer located on the University of Maryland campus. The information base will be stored and maintained in county extension offices throughout the state. County agents can also generate information about local concerns and put it directly into the system. Joining two familiar household appliances--the telephone and the television--with an inexpensive videotext terminal, the system will make every home or office a part of a large communications network.

o FACTS--The Fast Access Computer Terminal System, is a distributed data base system located at Purdue University in Indiana.

o FIRSTHAND--Based on French videotext technology known as "Teletel," the First Bank System of Minneapolis introduced its FIRSTHAND system last year, beginning with 15 pilot terminals in the rural area outside Fargo, North Dakota. Plans called for 285 terminals by mid-1982 in rural and suburban homes and small businesses, offering a variety of information accessed through a local telephone number.

o GRASSROOTS (TELIDON)--A project announced by Frittsco, Inc., the holding company of the "Bakersfield Californian" newspaper and Infomart, a Canadian firm. Electronic videotext information services to agriculturally-related industries in the San Joaquin Valley in California are scheduled to begin sometime this year.

o INSTANT UPDATE--This is a time-sharing information delivery system in Cedar Falls, Iowa, designed for the professional farmers of America.

o TELPLAN--A system at Michigan State University which offers agribusiness news and consumer services to approximately 400 users.

o THE SOURCE--The information system of "Reader's Digest" magazine which offers more than 1200 programs and services, many of particular use to the agricultural community.

I have only scratched the surface and named but a few of the systems under development to bring information quickly to users everywhere. Much has been written about the present "Age of Information," and the emphasis has often been on the array of electronic devices which can store, process, retrieve, and distribute information at incredible speeds and in a variety of forms. Those of you who read the Department of Agriculture's "Extension Review" magazine are aware that the 1982 summer issue featured electronic technology. It is a good place to find out what some of our state partners are doing with this marvelous communication tool.

As you can see from some of these new systems I have just described, there is a concerted effort within the Extension Service to make computer technology more accessible to state and county workers. Our researchers, too, will be doing their part to see that their research results enter these information channels so that they can be found by the users.

One example of the cooperation we are seeing with this proliferation of data bases containing research findings is one called the National Pesticide Information Retrieval System--NPIRS. NPIRS is under development by Purdue University under a cooperative agreement. It will provide a nationally accessible on-line data base containing information about all EPA registered pesticides. This information will be drawn and updated from the EPA files. It will provide readily accessible information for a variety of users about pesticides which are registered for use against specific pests on specific crops or sites. There will also be the opportunity for states to insert information about pesticides that are locally registered.

The intent of this system is to provide a single unified data base for use by researchers, educators, user groups, and the National Agriculture Pesticide Impact Assessment Program. All of USDA's Science and Education agencies--the Agricultural Research Service, the Cooperative State Research Service, the Extension Service, and the National Agricultural Library--are

cooperating in NPIRS along with Environmental Protection Agency, the Extension Committee on Organization and Policy, and industry representatives. In addition, USDA's Forest Service and Animal and Plant Health Inspection Service (APHIS) maintain contacts with the coordinating committee and are advised as developments take place.

One system--that was developed by the Extension Service in cooperation with the Control Data Corporation--will provide significant help to encourage private sector involvement in Government programs. As you know, this is a major goal of the Reagan Administration. The Extension Service in all of its educational programs makes extensive use of volunteers. A good example is the 4-H youth program which involves more than one-half million adult volunteer leaders. Many times there are volunteers who have unique special skills. The possibility for other states to draw upon and use these skills would enhance and expand the effectiveness of Extension's educational programs. Consequently, Extension will develop an on-line data base that will provide the capability to store and retrieve information about Extension program volunteers who are willing to make their skills available in other programs or in other states. This data base, called the Extension volunteer skills data base, is nationwide in scope. Participation is voluntary.

In mentioning some of our accomplishments and plans in the world of electronic communication we mustn't omit regional efforts which respond to needs. All four regions--North Central, Northeast, Western, and Southern--have plans underway for regional Computer Institutes. The North Central Computer Institute at the University of Wisconsin was established in cooperation with the W. K. Kellogg Foundation on July 1, 1981--the first of the regional centers to open.

Comprehensive plans for the operation of the institute are contained in a 70-page grant proposal document submitted to the Kellogg Foundation. Very briefly, however, the institute will provide technical information services support to the cooperative Extension, research and resident information functions of the North Central land-grant institutions.

The institute operates solely to provide technical information services to the member institutions. The institutions will provide policy determination, financial support, and administrative direction. Actually, the three million dollar project was funded in part by a 1.5 million dollar grant from the Kellogg foundation. The institute will try to reduce program duplication among states and assume projects which have been too costly for an individual state to undertake.

In January of 1982, USDA's Office of Governmental and Public Affairs in Washington, D.C., began electronic news dissemination through two electronic information systems. One was provided by DIALCOM, Inc., an international commercial firm headquartered in Silver Spring, Maryland. The other was provided by AGNET, which is operated by the University of Nebraska at Lincoln. As weeks passed, other services were added such as the "Farm Paper Letter," a weekly newsletter written primarily for farm magazine and newspaper editors and related agricultural communicators. It was

distributed by the new method. Then "FAS Reports," primarily centered around the Foreign Agriculture Service's weekly roundup of world agricultural production and trade, was added. By midsummer, "USDA Online" was carrying summaries of outlook and situation reports by the Economic Research Service and highlights of crop and livestock reports issued by the Statistical Reporting Service.

Plans are underway to include full texts of crop and livestock statistical reports and agency economic and statistical periodicals on the DIALCOM system. The only cost to USDA to enter the news releases and summaries is the few minutes--sometimes only a few seconds--that it takes to dial into the DIALCOM or AGNET computer.

USDA's pioneering in electronic news dissemination through the DIALCOM and AGNET systems has been noticed by other Federal departments and agencies. Representatives from the Departments of Commerce, Labor, Health and Human Services, and the Veterans' Administration have visited USDA and studied the electronic information dissemination operation.

It is difficult to speculate on what uses agriculture will make of the computer in 1990. During the late 1970's we were just beginning to demonstrate how computers could serve agriculture. University researchers and large agribusinesses and corporations were just starting to use computers in solving some of agriculture's management problems. Now, we see the technology of computers and telecommunications and office automation influencing our daily lives more and more. And the momentum is increasing.

This new information technology--new ways of generating information, handling it, retrieving it, communicating it, and using it--is also transforming the way we do science. For example, we have on-line data systems gathering and dispensing information around the world on an interactive live basis. And we have massive duplication of effort in building and utilizing these systems. One of our greatest challenges in agriculture is to develop logical and cohesive information systems that will meet the many and diverse needs of our cooperators and clientele. We face serious problems of information overload. We are generating information faster than we can assimilate it. The rate of technological development has been so fast that many of the benefits go undefined in the next wave of innovation.

In 1990, computers will doubtless be an indispensible "hired hand" to assist with record keeping, long-range planning, and day-to-day management decisions on many American farms. In 1990 computers will support many of the agribusiness activities in each county. Also, I predict that in 1990 there will be very few single discipline programs. Almost all programs will be interdisciplinary. Agricultural engineers or agricultural economists will often take the lead in developing application models, while specialists

in other areas will contribute their expertise. The dialogue with the user will be streamlined and continually updated in response to new ideas and feedback from users.

We will need to focus our work more closely in order to zero in on a problem as it is identified in a given area. I believe we will be more mission-oriented with a commitment at the policy level to get a certain job done in "X" number of years with "X" number of dollars. This is not unlike what is being done in the Defense Department when we say we will build the ABC weapons system in five or ten years with "X" millions of dollars.

We have been doing this to some extent. When we had a corn blight, we mobilized Extension people, scientists from industry, from the Agricultural Research Service, and from the universities. We all got together and found an answer. But that was done on a crisis basis. Once the crisis went away, we eased off, and each of us went back to his old path.

We need to retain NOT the frenzied activity of that time, but the SPIRIT. That doesn't mean we can't go on with our regular testing and work. But there must be a certain portion of our work that is future oriented, or we really aren't fulfilling our mission very well.

When a program is used over a broad region, it will need to be flexibile enough for local adaptation for users. I believe the interdisciplinary research approach will lend itself to this flexibility necessary for local adaptation. We have barely scratched the surface in the use of these powerful tools in agricultural research, development, and education. We must master their use and do it soon.

The best and most ingenious and creative research will be of little use until its results are communicated to users, to other scientists, and to our public clientele. We must strive for prompt communication to reduce the time lag in research application. Perhaps one of our biggest challenges will be dealing with science-related problems of national significance. We must find ways to use scientific and technical information quickly--to minimize the turn-around time--as we respond to the changing problems of an increasingly complex society.

In closing, please accept my very best wishes for a successful meeting. And now, I will be happy to answer any questions you may have.

(*Main Building, Beltsville, Agricultural Research Center, U. S. Department of Agriculture, Beltsville, Maryland;* Courtesy, the author)

PROGRESS AND COMMITMENT

by

PAUL A. PUTNAM

Since it was founded in 1910, the Beltsville Agricultural Research Center (BARC) has become representative of the total agricultural research community. It has a tradition of productivity in providing information to assure that each of us will have an abundant, safe, and nutritious supply of food. With such a mission our scientists and their associates stand firm in their commitment as public servants--they know that they serve an honorable and vital need to society and they are committed, that is, they are dedicated as scientists, as citizens, and as agricultural researchers. In these characteristics the Beltsville scientists are representative of the total agricultural research community.

Beltsville, while only one of many agricultural research facilities in the Agricultural Research Service (ARS) of the U.S. Department of Agriculture, is unique in several critical characteristics. Beltsville has the largest and most diversified full-time scientific research staff. Its staff is conducting research on most of the major agricultural commodities, the programs are heavily oriented towards the more basic type of agricultural research. Furthermore, these programs are committed solely to agricultural problems of regional and national significance and the scientists maintain several scientific collections of national and international importance.

Beltsville's scientists have cooperative arrangements with scientists at other ARS locations and with SAES scientists in most, if not all, of the 50 states and many foreign countries. Agricultural research is clearly international in scope.

Some of the other important characteristics of Beltsville are:

> The extensive interactions among our diverse scientific population resulting in the pooling of expertise, equipment, and other resources;
>
> Its accessibility to other scientists and to domestic and foreign government officials. For example, we have from 50 to 75 visiting scientists at Beltsville at all times. Internationally, Beltsville is one of the best recognized agricultural research locations in the world;
>
> Academically our scientists can interact within a few minutes with scientists at other Federal research laboratories such as NIH, Walter Reed, GSFC, PWRC, FDA, EPA or with scientists at universities such as Maryland, Johns Hopkins, Georgetown, George Washington, Howard, University of D.C. No other agricultural research facilities are located in such a favorable academic/research environment.

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The type of information above is only for background information. The major purpose of this paper is to provide selected samples of research progress and accomplishments during the last 12 months at Beltsville. This information itself can speak more eloquently than anything else regarding the mission, dedication, and accomplishments of agricultural research scientists. The examples were selected by the laboratory scientists and may or may not turn out to be the most significant of their total annual accomplishments as they bear the test of time. They are, however, representative of the progress being made.

In order to help you focus upon these accomplishments, I have grouped them into seven research categories: natural resources; plant production; plant pests; animal production; animal pests; research techniques, and health. As you read the brief descriptions, I suggest that you select three or four about which you would like to know more. You can then check with the BARC scientists or the National Agricultural Library for greater detail. To assist you in that regard, the laboratory and chief are identified at the end of each accomplishment statement. In addition, when the research results are ready for utilization or are now being utilized by the agricultural industry, that will be noted by the term "Technology Transferred."

Recent Research Results

Natural Resources:

- The effectiveness of pesticides in midwestern soils is decreasing. For example, the corn rootworm insecticide, Furadan (carbofuran), and the herbicide Eradicane have been reported as being less effective in recent years. Research scientists have discovered that these chemicals may be degraded by adaptation of increasing populations of soil microorganisms to the specific chemicals. Research is now being initiated to determine how to protect the chemicals or prevent the microbial adaptations.--Pesticide Degradation Laboratory/P. C. Kearney.

- Field studies in the vicinity of Maryland's Wye River have shown that partitioning of pesticides between soil, water, and air can be predicted on the basis of the chemical properties of pesticides. The studies have also revealed that herbicide movement is unlikely to adversely affect submerged aquatic vegetation in bay areas in which runoff water disperses. The intimate mixture of water, land, and agriculture on Maryland's Eastern Shore has provided a natural setting for studying the movement and distribution of pesticides and other trace organics in the environment.--Soil Nitrogen and Environmental Chemistry Laboratory/A. W. Taylor.

- Restoration of agricultural productivity of disturbed lands such as sand and gravel spoil may be successfully accomplished using municipal waste compost.--Biological Waste Management and Organic Resources Laboratory/J. F. Parr.

- Remote sensing of soil moisture determined to be feasible in spite of vegetation effects. Data collected over BARC plots using microwave radiometers showed that vegetation effects could be accounted for when the vegetation parameter was included and the appropriate wavelength was used. They cannot adjust for such heavy vegetation cover as in a forest but the results pave the way for wider use of microwave remote sensing.--Hydrology Laboratory/E. T. Engman.

- Treatment with the experimental chemical "EDU" (ethylene di urea) found to be effective in prevention of Ozone injury to snap beans and red clover in laboratory tests.--Plant Stress Laboratory/W. P. Wergin.

- Progress continues in research conducted to solve the N-fixation puzzle.

  a) Observations with legumes; in this case the peanut, indicate that some strains of Rhizobium (nitrogen fixing bacteria) are more efficient converters of gaseous N2 into forms that plants can utilize. Current research is being conducted to determine if efficient strains can be improved in order to provide subsequent rotational crops with adequate nitrogen.--Plant Stress Laboratory/W. P. Wergin.

  b) Fast growing Rhizobia strains from China are poor N-fixation performers when tested with commercial North American soybeans. The question to be addressed is whether or not we can take advantage of the fast growing strains by genetic manipulations.--Cell Culture and Nitrogen Fixation Laboratory/G. W. Schaeffer.

  c) Rhizobium has been found to carry resistance to multiple antibiotics. Information may be used for "engineering" Rhizobia and to follow Rhizobium population dynamics.--Cell Culture and Nitrogen Fixation Laboratory/G. W. Schaeffer.

Plant Production:

- Stimulating germination of dormant weeds in soils with "anesthetics" may provide a new approach to reducing annual weed problems by depletion of the soils' reservoir of weed seeds. Research has shown that many substances that behave as anesthetics in animals can induce germination of many kinds of dormant weed seeds. Types of chemicals that have been found to be very active in overcoming seed dormancy in fall panicum under laboratory conditions include ethanol, chloroform, and ethyl ether.--Weed Science Laboratory/D. L. Klingman.

- Germination can be improved in aging soybean seeds by slowing water uptake. Deterioration in aging soybean seeds makes the embryonic axis susceptible to water injury during imbibition. Research, however, has shown that injury may be avoided by reducing the initial rate of water uptake by imbibing the seeds for two hours on the biologically inert substance polyethelene glycol before germination.--Seed Research Laboratory/G. R. Chandra.

- Dwarf apple breeding lines have been developed. This has been achieved up until now by traditional and expensive grafting procedures. The Fruit Laboratory has developed genetic dwarf apple breeding lines which do not require grafting and special rootstocks for maintaining dwarfness. These breeding lines could bring down apple-tree size to that of a cotton plant! Trees planted close together in orchards with genetic dwarf trees have the potential to double the yield per acre and cause the same type of production revolution that the short stem wheat and rice created in grain production. Beltsville is the only place where such breeding material exists but breeding lines are under evaluation and will be released in 1983.--Fruit Laboratory/M. Faust.

- A new potato has been released to the growers in the Eastern United States. Gold Rus, a new long tuber-type russet potato variety, adapted to production areas from Maine to Florida, will be released to growers this fall. Gold Rus has very white flesh, is mealy in texture, and is a gourmet baking item. Its long tuber is ideal for processing into high-quality french fries with a minimum of oil content.--Vegetable Laboratory/R. E. Webb. (Technology transferred).

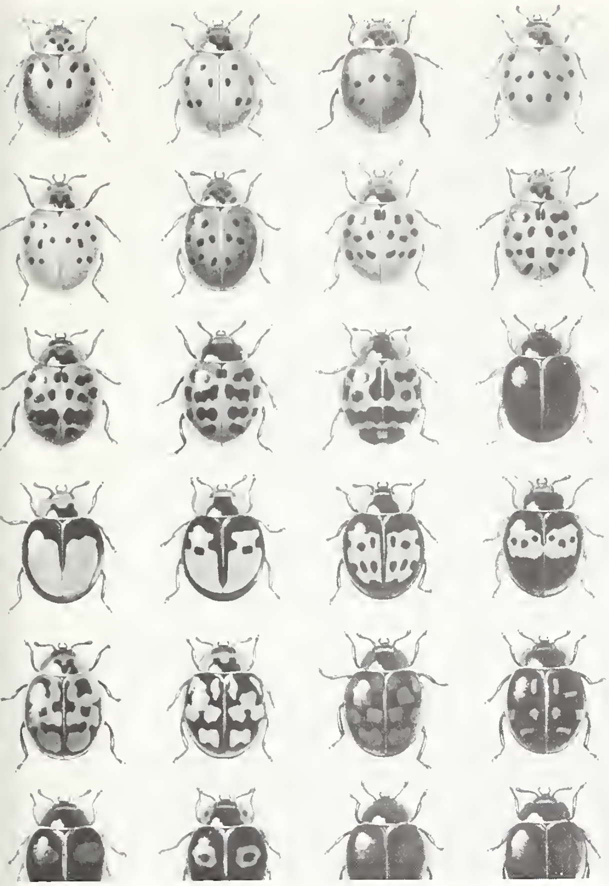
- New plant growth regulator has been economically synthesized. A number of brassinosteroids which are active analogs of the plant growth promoting hormone, brassinolide, have been synthesized. The availability of these steroids makes it possible for other plant scientists to study their brassin effects, mode of action, and potential to increase crop yield. In cooperative studies with the Plant Hormone Laboratory, one of these brassinosteroids has been shown to increase plant growth and yield in several vegetable crops.--Insect Physiology Laboratory/J. A. Svoboda.

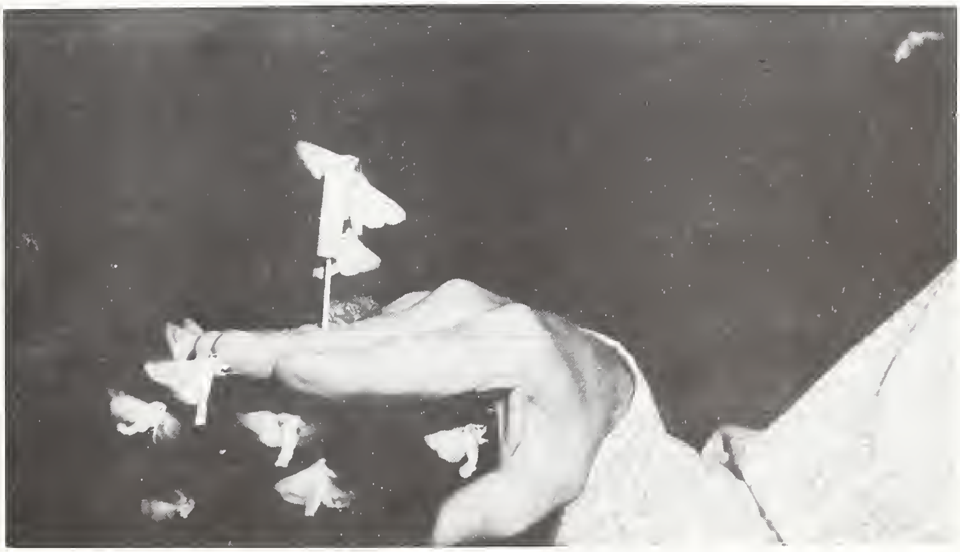
- Nitrogen photoassimilation has taken priority for plant energy utilization. This finding greatly expands the scope and importance of photosynthetic processes in plant productivity. The information resulted from studies on photosynthetic assimilation and translocation of carbon and nitrogen in crop plants.--Light and Plant Growth Laboratory/W. J. VanDerWoude.

- Tissue (anther) culture techniques have resulted in the successful production of haploid (half the number of chromosomes) plants in the laboratory. These procedures have produced unique variability in rice and wheat including enhanced dwarf types, increased seed size, seed yield, and protein content.--Cell Culture and Nitrogen Fixation Laboratory/G. W. Schaeffer.

- A new "Handbook of Legumes of World Economic Importance" has been published. This can be used as a reference source for scientists and producers alike.--Economic Botany Laboratory/J. A. Duke.

- Commercially available pollen substitute developed as a result of Beltsville research. The Beltsville Bee Diet is a pollen substitute that can replace pollen wholly for population buildup in early spring before natural pollen is available. The use of pollen substitutes and sugar syrup insures maximum populations of honey bees for honey production and pollination.--Bioenvironmental Bee Laboratory/H. Shimanuki. (Technology transferred).





(Top left, *All of the above pictured specimens are members of the same species, illustrating one of the problems associated with accurate insect identification;* Top right, *This newly introduced "beneficial insect," the hawk moth caterpillar, feeds on the weed pest, cyprus spurge;* Lower center, *Male moths respond to a synthetic copy of the females' sex attractant impregnated in a cotton roll;* Photographs courtesy of the author)

Plant Pest Control:

- o Insect testes have been found to produce hormones important in regulating life processes. The testis of the tobacco budworm (Heliothis virescens) has been discovered to produce ecdysteroids (insect hormones). Previously, only the prothoracic gland and ovaries were known to produce these hormones. The discovery points to a possible role of ecdysteroids in spermatogenesis.--Insect Reproduction Laboratory/ A. B. Borkovec.

- o Commercial feeding deterrent has been developed as a result of Beltsville research. An extract of the Indian neem seed applied to a susceptible crop as a spray or dust reduces or prevents feeding by more than 35 insect species of economic importance in the United States. Azadiractin, the active component, is effective at concentrations as low as 0.1 ppm. Such destructive insects as the Japanese beetle, Mexican bean beetle, Colorado potato beetle, and gypsy moth are among those affected by the feeding deterrent. --Biologically Active Natural Products Laboratory/M. Jacobson. (Technology transferred).

- o The Bagworm sex attractant pheromone has been isolated, identified, and synthesized. The insects attach their bags to host trees and cause damage estimated at millions of dollars in the southern States. The pheromone has a novel structure and is now being produced commercially and traps were available this fall.--Organic Chemical Synthesis Laboratory/J. R. Plimmer. (Technology transferred).

- o Five lines of soybeans resistant to Mexican bean beetles have been released. The result of cooperative research, this represents the first release of insect-resistant soybean germplasm in the United States. The new lines yield approximately 50 percent more than standard susceptible cultivars when severe Mexican bean beetle infestations occur but are slightly lower yielding in the absence of the beetle. It is expected that plant breeders will incorporate the insect resistant characteristics into their high yielding cultivars of the future.--Field Crops Laboratory/ J. H. Elgin. (Technology transferred).

- o Control of five plant viruses are expected to be improved by the successful production of specific monoclonal antibodies. This will be of major importance in the identification of specific viruses and the classification of disease agents because the antiserum is highly specific for single antigenic sites of a complex viral antigen. The practical application of these monoclonal antibodies will be in field diagnosis of virus diseases.--Florist and Nursery Crops Laboratory/ R. Lawson.

- o Biological control of wilt in the eggplant is now possible. A newly discovered fungus, Talaromyces flavus, suppressed Verticillium wilt of eggplant in the field. Application of the beneficial fungus gave us good control of the disease as the high rate of the recommended fumigant. The beneficial fungus reduced disease by 76 percent and

67 percent and increased yields by 71 percent and 22 percent in Centerton, New Jersey, and Beltsville, respectively. This is the first report of a beneficial fungus being used to control Verticillium, an important pathogen of many economic plants.--Soilborne Diseases Laboratory/G. C. Papavizas.

- Plasmid carrying gene for production of insect toxins has been identified. The plasmid was identified in a strain of Bacillus thurengiensis that has shown a high level of toxicity for several species of mosquitoes. This discovery is the first step toward the genetic engineering of new strains of this bacterium that produce toxins with broader host ranges or increased potencies.--Insect Pathology Laboratory/J. L. Vaughn.

- Colorado Potato Beetle parasite has been established experimentally. An Australian mermithid that parasitizes the Colorado Potato Beetle has been established in cages under field conditions and is now being evaluated for efficacy and safety of release in the United States. This nematode effectively controls the very damaging potato beetle in Australia. --Nematology Laboratory/R. V. Rebois.

- Bean rust has been controlled by bacterial spray. Cultures of Bacillus subtilis sprayed onto bean plants have been found to protect the plants against bean rust caused by the fungus Uromyces phasioli. Current research suggests that the active component is a negatively charged polysaccharide which is effective against rust at levels as low as 10 parts per billion and is apparently not toxic to humans. Preliminary field tests show the polysaccharide to be effective against rust.--Applied Plant Pathology Laboratory/A. G. Gillaspie.

- Two "immigrants" may be controlling some of your weeds in the future. Two beneficial insects have been established in the United States for the first time for biological control of weeds. A European fly, Urophora cardui, which forms damaging galls on Canada thistle, and a hawk moth, Hyles euphorbiae, whose caterpillars feed on the foliage of cyprus spurge, became established in Maryland and New York in 1981 and 1982. These insects are expected to have an impact on thistle and spurge populations in about three to five years. Prior research has shown that they pose no danger to any economic plants in the United States.--Beneficial Insect Introduction Laboratory/J. R. Coulson. (Technology transferred).

- Proper identification is essential for insect control. There are about one million described species of insects and mites, and three to ten times that many more undescribed species. The variation within many of these species adds considerably to the difficulty in making accurate identifications. For example, a single species of an aphid predator may have as many as 24 color patterns.--Systemetic Entomology Laboratory/L. V. Knutson.

Animal Production:

- Milk energy yield was increased 27 percent by growth hormone in spite of a slight reduction in the feed intake. Growth hormone was found to cause a dramatic shift in the partition of available energy away from body tissue and towards milk. Results obtained by using respiration chambers and

high producing cows indicate that exogenous growth hormone does not change metabolic efficiency of milk synthesis but does increase the rate of milk synthesis and mobilization of body fat reserves. --Ruminant Nutrition Laboratory/P. W. Moe.

- o Fresh turkey semen can now be held up to six hours without loss in fertilizing capacity. Currently, the turkey industry relies solely on artificial insemination (AI) as a means of reproducing turkeys. Annually AI costs the turkey producers about 12 million dollars. Holding turkey semen for six hours before AI will lower costs by reducing labor and number of male turkeys needed. The accomplishment has the potential for saving the turkey breeding industry about six million dollars annually.--Avian Physiology Laboratory/T. Sexton. (Technology transferred).

- o Turkey embryos have been cultured successfully ex ovo up to 17 days. Treatments in aqueous form can be applied directly to the chorioallantoic membrane and are readily absorbed into the embryo. Current research using this technique involves investigations of trace element metabolism and endocrine control mechanisms for embryonic calcium metabolism.--Nonruminant Animal Nutrition Laboratory/N. C. Steele.

- o Blood cell hormone binding will be used to predict an animal's genetic propensity for fat and lean tissue accretion. For example, using this technology, it has been determined that there was increased hepatic insulin binding as a result of low protein intake by swine which explains why swine fed low protein diets have excessive body fat accretion with reduced blood insulin.--Nonruminant Animal Nutrition Laboratory/N. C. Steele.

- o USDA/DHIA sire summary can now be used to select bulls with genetic merit for milk protein and solids-not-fat. Pricing milk on favorable nutrient components is increasing in practice. The sire summary is based on information on milk protein and solids-not-fat yield of individual cows to provide improved genetic information on sires for dairymen whose milk is priced on additional milk components besides fat content.--Animal Improvement Programs Laboratory/F. N. Dickinson. (Technology transferred).

- o An encouraging advance has been made towards predetermining sex of cattle and swine. Flow cytometory has been used by Beltsville/State/and industry scientists to verify DNA content of X and Y chromosome bearing sperm from bulls and boars. X chromosome bearing sperm had nearly 4 percent more DNA than Y bearing sperm. The procedure can now be used for testing samples of semen which have been subjected to separation procedures for confirmation of a sex ratio change.--Reproduction Laboratory/H. W. Hawk.

Animal Pest Research:

- o Trap has been developed that is effective in multiple trapping of face flies, stable flies, and horse flies. All of these flies are pests to the livestock population and cause production and management problems.--Livestock Insects Laboratory/D. K. Hayes.

- Success has been achieved with _in vitro_ inhibition of an avian coccidia by hybridoma antibodies. Exposing sporozoites (a stage in the development of an avian coccidia) to monoclonal antibodies directed specifically against this stage dramatically inhibited penetration of cultured primary chicken kidney cells and the subsequent intracellular development of these parasites. Efforts are currently underway to determine if those antigens will elicit a protective immune response in birds.--Poultry Parasitic Diseases Laboratory/M. D. Ruff.

- Identification of antigens from the swine parasite, _Trichinella spiralis_, has been accomplished using hybridoma-derived monoclonal antibodies. The project is now aimed at isolation and characterization of these antigens for eventual incorporation into large-scale production procedures.--Nonruminant Parasitic Diseases Laboratory/ K. D. Murrell.

- First bovine monoclonal antibodies have been obtained. These antibodies will be used in basic studies of the dairy cows' defenses against mastitis, a disease causing losses of some two billion dollars every year.-- Milk Secretion and Mastitis Laboratory/R. H. Miller.

- Certain rapid cooking techniques with meat may not destroy trichinae. In experimental tests, pork chops thawed to $0^{o}C$ in commercial microwave ovens and then charbroiled to an internal temperature of 66, 71 or 77oC contained some motile trichinae. Research is now underway to verify the thermal death times and temperature for _Trichinella spiralis_ larvae.--Meat Science Research Laboratory/A. W. Kotula. (Technology transferred).

Techniques Research:

- New technique has been developed for utilizing a Fourier Transform Infrared Spectrometer as a selective detector for the liquid chromatographic determination of certain pesticides. Although not yet approaching the well-established gas chromatograph by mass Spectrograph combination in sensitivity, the new technique provides a potentially valuable tool for more positive identification of pesticides at residue levels.--Analytical Chemistry Laboratory/K. R. Hill.

- New techniques have been developed for detecting the immune responses of cattle and sheep infested with the parasite _Sarcocystis_. One technique is called the ELISA test (for Enzyme-Linked ImmunnoSorbant Assay), another technique measures the activity of certain white blood cells in response to infection and is called the lymphocyte blastogenesis test. The third technique requires injection of minute quantities of parasite antigen into the skin. These techniques are being used to study the nature of the host immune response for development of effective vaccines and as a diagnostic test for sarcocystosis in farm animals.--Ruminant Parasitic Diseases Laboratory/ R. Fayer.

- Identifying characteristics of important parasites of sheep, cattle, and goats have been discovered. The number and distribution of cuticular ridges on the body surface of the genus Nematodirus can be used to determine the species of both male and female nematodes. This new characteristic can be observed in living specimens and may become the most useful identifying feature of these nematodes.--Parasite Classification and Distribution/J. R. Lichtenfels.

- A new apple evaluation technique has been developed to monitor textural qualities after harvest. Attributes measured include crispness, juiciness, hardness, and mealiness. Sensory profiles are measured, a force/deformation spectrum is recorded, and the values are used in a regression equation to determine textural quality.--Horticultural Crops Quality Laboratory/A. E. Watada.

- High resolution, two dimensional, chromatography technique has been developed to study synthesis and degradation of individual polypeptides during soybean seedling development. Computer facsimiles of auto radiograms are utilized to determine percentages of individual polypeptides. These techniques are being used in taxonomical studies to determine the effect of plant hormones on protein biosynthesis.--Plant Hormone Laboratory/J. D. Anderson, Instrumentation Research Laboratory/K. H. Norris.

- Successful separation has been achieved of identical size RNA molecules called "CARNA-5_s." These small RNA molecules with different nucleotide sequences are found in association with cucumber mosaic virus a ubiquitous plant pathogen. The separation of these molecules is an essential prerequisite towards understanding and possibly exploiting their disease regulating capabilities.--Plant Virology Laboratory/R. L. Steere.

- Rapid non-destructive measurement of oil, moisture, and protein in a seed is now possible using a near-infrared transmittance technique. The technique can be used to predict individual seed composition for breeding purposes or for predicting sample composition for marketing. The procedure has been successful on both soybean and sunflower seeds. --Instrumentation Research Laboratory/K. H. Norris.

Health and Safety:

- Botanical expertise for identifying plants contributes to search for anti-cancer (anti-tumor) agents in plants. Cell culture and animal screening techniques at NIH have identified several active chemicals.--Plant Exploration and Taxonomy Laboratory/R. E. Perdue

- Alpha particles of Polonium-210 have been shown to be present in throats of animals exposed to high Polonium-210 experimental cigarette smoke. The effect is reversible when exposure to smoke is stopped. These findings indicate clearly that Polonium-210 is a potential health factor. Methods are now being developed to reduce or remove polonium from leaf tobacco produced under natural field conditions. --Tobacco Laboratory/T. C. Tso.

Isolated soybean protein has been observed to depress availability of iron and zinc to humans as compared to diets containing textured soy or animal protein diets. The significance of this observation is now being studied in longer term experiments.--Beltsville Human Nutrition Research Center/C. E. Bodwell.

The above accomplishments illustrate the breadth of agricultural research and the exciting new discoveries that will indirectly and directly affect man. I also hope that these observations will give you a greater appreciation for what agricultural research, as a public service, is doing for you and society in general. It has been estimated that your tax investment in agricultural research is paying a 50 percent annual dividend. That sounds like a good investment to me.

USDA SCIENTISTS: SELECTED PROFILES, CHALLENGES AND ACHIEVEMENTS

by

WAYNE D. RASMUSSEN

Over four decades ago, then Secretary of Agriculture Henry A. Wallace wrote: "Science, of course, is not like wheat or cotton or automobiles. It cannot be overproduced.... Moreover, knowledge grows or dies.... It is perishable and must be constantly renewed.... Our investment in science would vanish if we did not freshen it constantly and keep in training an alert scientific personnel."[1]

As the 1980's unfold, agricultural research is under attack as being both overproduced and produced for the wrong people. Funds for research, particularly basic research, are scarcer than they were a decade earlier, so the scientist must spend more of his time justifying and searching for the funding he needs. This means that the alert scientist Wallace called for uses more hours on writing grant or other funding proposals and fewer hours on actual research.

The changing perspective on agricultural research has resulted largely first, from a questioning of the focus of research by outside critics such as Rachel Carson and Jim Hightower and, second, from criticisms of the quality of research by a committee of the National Research Council chaired by Dean Glenn S. Pound of the University of Wisconsin and by others. Carson, in her book Silent Spring (1972) and Hightower, in his Hard Tomatoes, Hard Times (1973), argued that research was too narrowly directed to plants, animals, and soils, to the neglect of problems of rural communities and consumers. The Pound Committee report indicated that much agricultural research was outmoded, pedestrian, and inefficient.[2]

Nevertheless, research does continue in the Department. Today's scientists are direct heirs of a productive past that has eliminated famine as a continuing threat to much of the world's population. Who were these scientists of the past who have left us their heritage of achievements?

Every agricultural scientist, whether employed by the United States Department of Agriculture, by a land-grant university, or by a private firm is, of course, an individual with his or her own individual strengths and weaknesses. If, however, we divide scientists into groups by the kinds of activities that characterize their most important contributions to the world of science and to their fellow human beings, it may be possible to determine some of the characteristics of successful scientists. Thus, we might examine the work of each scientist from the viewpoint of the scientist as a researcher, the scientist as an administrator, and the scientist as a policy maker or a public leader. Obviously, each outstanding scientist will probably have worked as a researcher and as an administrator and, possibly, as a policy maker or public leader. Determination of the group into which a particular scientist might best be classed, therefore, must be rather arbitrary.

The researcher is the quintessential scientist. The administrator and the policy maker are there to facilitate research and to bring it to bear on public needs. Without the researcher, the scientist as administrator and the scientist as policy maker are nothing. Yet the researcher is usually not as well-known as either the administrator or the policy maker.

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In this paper, discussions of individual researchers, administrators, and policy makers will emphasize achievement by individuals representing different time periods and different sciences. Those discussed will be people whose careers were primarily in the Department of Agriculture and who are deceased. The selections will, of necessity, be like their classification, arbitrary and based in part upon the availability of material regarding their careers and personalities. These selections will also be limited to persons whose work was done during or reached into the twentieth century.

As the nineteenth century gave way to the twentieth a flowering of agricultural research resulted in the establishment of principles that have affected every aspect of agricultural production and the welfare of the nation. Scientific knowledge, support for research, and the needs of commercial agriculture coincided in bringing about fundamental changes in American agriculture. These changes often came about because of the determination and leadership of an individual scientist as the following examples will demonstrate.[3]

The commercial cotton farmers of the South were threatened at the turn of the century by cotton wilt. Wilt is a fungus disease that lives indefinitely in the soil; it kills and damages plants by stopping up the root systems. In 1899 the task of investigating cotton wilt was assigned to William A. Orton, a young plant pathologist from Vermont. Orton first visited the islands off the coast of South Carolina, where long-staple cotton in particular had suffered from the disease, although wilt was spreading to upland cotton as well. There Orton met a grower named Elias L. Rivers who pointed out that a few plants often survived in a field attacked by wilt. Rivers had been saving seed from these resistant plants. Orton encouraged Rivers to continue his work in the hope that he would develop wilt-resistant varieties of upland cotton. The work, undertaken near Dillon, South Carolina, was so successful that Orton reported on it in a bulletin published in 1900.

The long-term control of cotton wilt by breeding disease-resistant strains was of tremendous importance to cotton growers. The theory of selective breeding for plants resistant to disease developed by Orton has since been applied to most of the major crops grown by the American farmer. In addition, the principle of selective breeding has been extended not only to resistance to disease but also to resistance to insects and to drought adaptation to differing climates; it has also improved flavor and marketing qualities and increased food value.[4]

It sometimes is not enough for a young scientist to seize on a new idea or on a new application of an idea. The researcher may have to overcome some theory that has either become a canon in the field or has been embraced by the hierarchy in which the scientist is working. Marion Dorset found himself in the latter situation when he came to work for the Bureau of Animal Industry (BAI) in 1894. The chief of the bureau, an authority on livestock diseases, had published a paper reporting his discovery that hog cholera was caused by a bacterium. Dorset was assigned to find a preventive or cure or, more specifically, to test a serum that his superiors had prepared in the BAI laboratories that they felt would control the disease. He tested the serum in an outbreak of hog cholera in Iowa in the summer of 1897 but found that it did not protect the animals.

Back in Washington, Dorset, with the support of his immediate supervisor, E. A. deSchweinitz, undertook new investigations which proved that hog cholera was not caused by a bacterium but by a virus. He also proved that hogs that recovered from the disease were immune for life. During another major outbreak in Iowa in 1903, Dorset, with the help of other investigators, found that injecting well hogs with blood from hogs that had recovered from the disease gave temporary immunity. Then Dorset developed the idea of using two injections. The first was done using blood from a hog that had survived an attack and the second was done using blood from an infected hog. This treatment, with slight modification, was used to bring hog cholera under control. Its virtual eradication, however, awaited a new generation of scientists as administrators who undertook a program of destroying affected herds. Dorset himself made many additional contributions. He was one of the first scientists to make chemical analyses of the tubercle bacillus and to organize the system of Federal inspection of veterinary biological products that continues, of course with modifications, to the present.[5]

While some researchers such as Orton and Dorset were seeking the answers to plant and animal diseases others, known as plant explorers, were scouring the world to find new crop plants and more productive and disease-resistant varieties than those already grown here. These adventurous inquiring searchers included David Fairchild, Mark Carleton, Frank N. Meyer, and Palemon H. Dorsett.

The plant explorers had broad interests, introducing an almost limitless number of plant varieties. Dorsett made the first trips to China and Manchuria in search of soybeans. When he began his work, not more than eight varieties were grown in the United States. Dorsett was joined in his search by a younger man, William J. Morse. In the spring of 1931, Dorsett and Morse returned from two years in the Orient, bringing with them some 3,000 varieties of soybeans. By this time, Morse, an unassuming but persistent researcher, had determined to devote his life to soybean improvement. It was about then that the large-scale production of soybean oil began. A method of processing the oil, which eliminated a disagreeable odor from the finished product, markedly increased the use of the oil in the food industry. From the 1930's on, Morse wrote bulletins advising farmers how to grow soybeans, discussed possible uses for the crop in Departmental yearbooks, continued to introduce new varieties, and worked to improve those already being grown. While many other scientists contributed to making soybeans one of the most important crops grown in the United States today, Morse's name is still preeminent.[6]

While a man like Morse devoted himself primarily to the improvement of a single crop, there were a few scientists who moved from one major research field to another. Such a person was William J. Spillman. He began his scientific career at a land-grant college, Washington State, as did many other well-known Departmental scientists. Spillman soon recognized the importance of wheat to eastern Washington and set out to breed more useful varieties for the region. He rediscovered Mendell's law when he found that the wheat he grew in various combinations of varieties resulted in recombinations of the original parent characters and nothing else. However, even this discovery was useful and Spillman's work led to the development of several productive hybrid club wheats.

In 1902, Spillman joined the staff of the Department of Agriculture in Washington, D.C., as agrostologist in charge of grass and forage plant investigations. He then began to study farming methods and types of farming. His work led the Department to establish an Office of Farm Management, with Spillman as its head. Spillman remained in this work, except for a short period as a farm editor, for the rest of his life. Spillman originated farm management surveys as a method of studying farm problems, devised the dot-map method for presenting statistical data, encouraged county agent work in the northern states, directed historical and geographical studies, and published a careful analysis of the domestic allotment proposal for farm aid in 1927. He was the first president of the American Farm Economic Association known today as the American Agricultural Economics Association.[7]

Spillman, with his wide-ranging interests and accomplishments in many fields of agricultural research, was a combination of the scientist as researcher and the scientist as administrator. A young man who joined the Department as an agricultural economist and historian demonstrated what a hard-driving, intellectually curious, middle-level scientist as administrator could accomplish. In 1922, Oscar C. Stine became director of the Division of Statistical and Historical Research, a position in which he made major contributions to the Department and to American agriculture.

Work under Stine's direction resulted in the following accomplishments: the first commodity outlook and situation reports; the first outlook conferences; the organization of foreign agricultural research, leading to the establishment of the Foreign Agricultural Service; the development of new statistical techniques, and the development of measures of food costs and food consumption. Most of the nation's leading agricultural economists into the 1950's worked under Stine's direction at one time or another. Stine himself served as president of the American Farm Economics Association, the American Statistical Association, and the Agricultural History Society.[8]

Stine probably violated all of the rules of effective management. His policy was to hire people whom he believed could carry on effective independent research. He would discuss some idea with the new researcher and suggest that that person look into the problem. After some months, if the researcher had not taken the initiative by sending a manuscript to Stine, he would be called to the front office. If he convinced Stine that he was working hard and was coming up with reasoned conclusions, even through they might not agree with Stine's ideas, he received assignments from Stine, was protected from having to spend time on administrative chores, and was promoted regularly. If he failed this first test, the researcher was well advised to look for a job elsewhere. Out of such an atmosphere came many of the lines of work and approaches to problems that are found in today's Economic Research Service.

John R. Mohler, Chief of the Bureau of Animal Industry from 1917 to 1943, was an entirely different type of scientist as administrator. A veterinarian, Mohler started his career as an assistant inspector of livestock. He moved steadily up the career ladder, working closely with his associates and superiors. A politician in the best sense of the word, he kept in touch with the livestock industry, the changing Secretaries of Agriculture and their staffs, his associates in the Bureau, and those who worked under his supervision. Yet, at times of crisis, when the American livestock industry was threatened with hoof-and-mouth disease, he moved quickly and decisively to bring the full powers of the Bureau and the Department to action in stamping out the threat. He was sometimes cited as a model of the effective scientist as administrator.[9]

The administrative style of Louise Stanley, the first Chief of the Bureau of Home Economics, was more like that of Mohler than of Stine. One of Stanley's immediate actions was to obtain advice from the national women's organizations as to fields of research for the new Bureau. These groups were to give her strong support during the 20 years from 1923 to 1943 that she served as chief. She needed this support as she led her staff into research on various aspects of diet and nutrition. At one time or another, her Bureau was denounced by oleomargarine manufacturers, milk producers, flour millers, and wheat growers. Stanley, however, backed the scientists in the Bureau and encouraged them to move into new aspects of nutritional research.[10]

While Stanley was a spokesman for the nutritionists, chemists, and others in the Bureau of Home Economics, she remained the scientist as administrator, in contrast to others who became scientists as policy makers or advocates. The Department of Agriculture has been unusual among government agencies in that many of its most effective policy makers over the years have been trained scientists who were willing to risk their careers to advance programs in which they believed. Of course, not every program advocate risked his career. For example, Seaman A. Knapp had a successful career as a college president, rice planter, and plant explorer behind him when he began work for the Department at the age of 70. He was asked to undertake research on the problems of raising cotton in areas infested with the boll-weevil. Knapp worked with practicing farmers to demonstrate that cotton could be raised in spite of the weevil by using earlier varieties and better farming methods. His approach was welcomed and led directly, with somewhat similar work being conducted in the North and West by William J. Spillman, to the county agent system and the Cooperative Extension Service.[11]

In contrast to the early widespread acknowledgement of the value of Knapp's proposals, Harvey W. Wiley was a controversial figure throughout most of his career. In 1883, he was appointed chief chemist of the Department where he remained until his resignation in 1912. His first assignment was to conduct research to make the United States self-sufficient in sugar production. Wiley put a great deal of effort into the project but a series of

misadventures and the basic technical difficulties that existed, combined with political pressures, led to delays in the work and demands for Wiley's resignation. He weathered the storm, however, and helped reestablish the sugar-cane industry in Louisiana and in Florida.

The unjust criticism Wiley endured while working with sugar strengthened his natural inclination to decide for himself what was right and then to move on toward his objectives disregarding all obstacles. Early in his career in the Department, Wiley became convinced that adulterated food and drugs were both a fraud and a danger to the health of the public. Even before Wiley joined the staff, Departmental chemists had been concerned with the problem. Wiley turned this concern into a crusade but a crusade backed by careful sound research.

Wiley was anxious to demonstrate his research in ways that would command public attention. In 1902, he recruited a group of young men to eat food purchased on the market which, like much other food at the time, was preserved by chemicals Wiley considered dangerous. Wiley not only kept careful records of the experiment, he also publicized the experiment as the work of the "poison squad."

As a result of Wiley's continuing work in calling the public's attention to the dangers of adulterated food and drugs, Congress passed the Food and Drug Act of 1906. This legislation, still basic to the well-being of the American people, was largely the result of the determination of one scientist as policy maker--Harvey W. Wiley.[12]

Wiley was an eminently qualified scientist before he began his efforts to secure legislation that would protect the consumer from adulterated food. Another eminent scientist as policy maker was one of the best trained foresters in the United States when he began his work to establish the Forest Service in the Department. During his 12 years of government service, Gifford Pinchot brought about the establishment of the Forest Service, made Americans aware of the importance of forests and other natural resources, and saw the forest reserves grow from 40 million to 200 million acres during his term in office. Pinchot was a natural resource conservationist all of his life and was able to imbue others with his enthusiasm. He expected loyalty and dedication from those in the Forest Service and started the Service on its way to becoming recognized as one of the consistently best managed of all Federal agencies.

Pinchot received his scientific training in Europe. Another leading conservationist of a later generation, Hugh Hammond Bennett, was a graduate of the University of North Carolina who learned about soil erosion through his work as a soil surveyor for the Department. He saw what was happening to the soil, particularly in the South, through both sheet erosion and gullying. In 1928, the Department of Agriculture published his bulletin,

"Soil Erosion a National Menace." This publication has been regarded as a turning point in Bennett's fight for recognition of the problem.[13]

In the 1930's, the devastation of erosion became apparent to the entire nation, particularly because of the Dust Bowl. A Soil Erosion Service was established in the Department of the Interior with Bennett as its head. In 1935, aware of the menace of erosion, Congress transferred the Soil Erosion Service from the Department of the Interior to the Department of Agriculture and, later, established the Soil Conservation Service, its successor, as a permanent agency.

Bennett had a flair for the dramatic, somewhat in the tradition of Wiley. The story is told that when a Senate committee was considering a bill to establish the Soil Conservation Service, Bennett learned that an intense dust storm was approaching Washington from the west. Carefully tracking the storm, Bennett delayed the Senate hearing until the dust was due to hit Washington. As the hearings went on one afternoon, the sky darkened and Bennett called the Senators to the windows of the hearing room. "Gentlemen," he said, "that is Kansas blowing away." The committee immediately approved the bill to establish the Soil Conservation Service.

Bennett continued to head the expanded work. Like Pinchot in the Forest Service, Bennett demanded loyalty to the program and, in turn, gave his full support to the staff members of the Soil Conservation Service. Eventually, Bennett was to see virtually the entire nation organized into soil conservation districts, all applying the principles of conservation science.[14]

The examples that have been cited emphasize individual scientists, whether working as researchers, administrators, or policy makers. Many other researchers could be listed. For example, from 1905 to 1919, Mary Pennington worked on food preservation, particularly on refrigeration. Her work to improve refrigerator cars during World War I brought her to public attention and an offer of a job in the private sector paying twice her government salary.[15]

George Washington Carver, a cooperative agent of the Bureau of Plant Industry, was at Tuskegee Institute from 1896 to 1943. He devoted his career to developing new uses for farm products and encouraging poor farmers to adopt simple methods for improving farm production and bettering their lives.[16] An entomologist, G. F. White, discovered that "milky spore disease" would control the ravages of the Japanese beetle.[17]
From the 1920's until the 1960's, Elmer A. Starch, a specialist in farm management, helped make dryland agriculture more productive, first in the Great Plains of the United States and then in the dryland regions of Turkey and Tunisia.[18]

Scientists as administrators include Claribel R. Barnett who, from 1907 to 1940, served as the Librarian for the Department. She brought library science to the service of researchers and made the USDA Library the world's preeminent collection of agricultural literature.[19] From 1909 to 1935, Curtis F. Marbut built up a body of soil science that fitted conditions in the United States.[20] Henry C. Taylor, the first head of the Bureau of Agricultural Economics and a determined if irascible scientist, brought economics to bear as a unifying force for studying farm problems.[21] Morris Llewellyn Cooke, a mechanical engineer, developed the background for the Rural Electrification Administration and, as head of that agency, began a program that was to provide electricity to virtually every farm in the nation.[22] Finally, looking at scientists as policy makers, it might be well to mention James Wilson, Secretary of Agriculture from 1897 to 1913. He built the Department into what was then the greatest scientific research institution the world had seen.[23]

No scientist truly worked alone even though some felt that they had to fight both for their ideas and for the support they needed to carry on their work. Those who moved ahead to become policy makers knew that they were entering arenas where they were risking their future careers, and some lost. Yet, for most scientists, the Department offered a secure base from which to carry on their work. In a recent study of the comparative success of New Deal farm programs, the authors conclude that "agricultural experts, their ideas, and the administrative means they could use to implement the ideas all were products of a long process of institution building whose roots go back to the Civil War, when the U. S. Department of Agriculture was chartered and the Morrill Act was passed."[24]

The interactions among the major institutions--the Department, the land-grant universities, and the general farm organizations--provided an atmosphere in which scientific research could flourish, at least up until recent times. Institutions could provide the atmosphere in which science would flourish but it was still up to the individual to achieve.

This very brief look at only a small sample of the Department's outstanding scientists from the turn of the century to the end of World War II leads to certain limited conclusions as to characteristics they might have in common. These outstanding scientists attacked problems with determination. A Spillman might find that his first work in cross-breeding wheat led to nothing new but he would persist. Persistence in the face of obstacles and even opposition was another mark of the successful scientist. A Stanley, in conducting research into healthful diets, might be opposed by strong financial interests, but he would still continue with sound provable work.

Originality in thought and in experimentation was obviously a characteristic of the scientist who would leave his mark on his profession. Dorset would question his chief's conclusions when they did not prove out and would develop his own theories and conduct his own experiments. The most

successful scientists had a large measure of self-confidence, believing in the work they were doing and in their abilities to carry this work to a successful conclusion. A Mohler, backed by a dedicated staff, knew that he could keep hoof-and-mouth disease from becoming established in the United States. Finally, the scientist as policy maker was most successful if his research had led him to the conviction that a particular policy or program would greatly benefit the people of the United States and he would then devote his career to that cause. A Bennett could undertake a crusade for soil conservation that would help change the face of a nation.

Determination, persistence, originality, self-confidence, and devotion to a cause are values that are not, of course, unique to scientists or, particularly, to USDA scientists. Nevertheless, they are the qualities of the USDA scientists as researchers, administrators, and policy makers who have helped make American agriculture one of the great hopes of the world. If famine in the world is to be finally conquered, and it virtually is, then the American people must maintain the institutions that have supported and brought forth the achievements of an unsung American hero--the agricultural scientist.

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UNDERINVESTMENT IN AGRICULTURAL RESEARCH AND MAN-MADE FAMINES: CHINA AS THE CASE STUDY

by

WILLIAM A. DANDO

INTRODUCTION

China, a unified multinational political entity, is the third largest country in the world and Chinese agriculturalists provide sustenance for approximately 23 percent of the world's population on only eight percent of the world's arable land. Measuring east-to-west over 5,000 kilometers and north-to-south over 5,500 kilometers, China's total land area exceeds 9.6 million square kilometers. A high proportion of this vast country is unsuited for intensive traditional agriculture and only 12 percent of China is currently under cultivation.[1] Agriculture, the foundation of the nation's economy, provides a livelihood for nearly 80 percent of the population and produces a high percentage of the national income. Because China is a a country with great climatic, landform, vegetal, and soil diversity, Chinese agriculturalists are able to produce virtually every kind of food or technical crop and food animal. Grain crops, Chairman Mao's "key link," account for 80 to 90 percent of the total sown acreage.[2] Expansion of cultivated area with current technology appears unlikely.[3]

Agro-climatic resources and physiogeographic characteristics vary sharply and in a north-to-south alignment. In this predominantly agrarian society, climate has a dramatic effect on human activities and food availability. Chinese literature is replete with references to flood and droughts. Drought in China is a condition where water needs for agricultural and industrial use are in excess of available moisture. Reduction of agricultural yields to drought induced plant damage is a matter of decreasing the water need by not cultivating land, of planting crops that do not require moisture in excess of a normal standard deviation for an area, or of increasing water supply from another source to plants. Concomitantly, crop selection, crop improvement, careful development of plants of a particular type that have low water demands, soil-moisture retention, and cultivation practices, and weed control help reduce the water need. Chinese agriculturalists are masters of traditional agricultural practices and have developed varieties of crop plants to withstand moisture stress, while constructing elaborate irrigation systems for providing all or part of the water need for crops in irrigation districts (Figure 1). Limitations to Chinese irrigation schemes and practices include the availability of water from surface or ground-water sources and the cost (in labor, material, and time) of diverting water to suitable fields. Almost one-half of China's cultivated areas are irrigated.[4]

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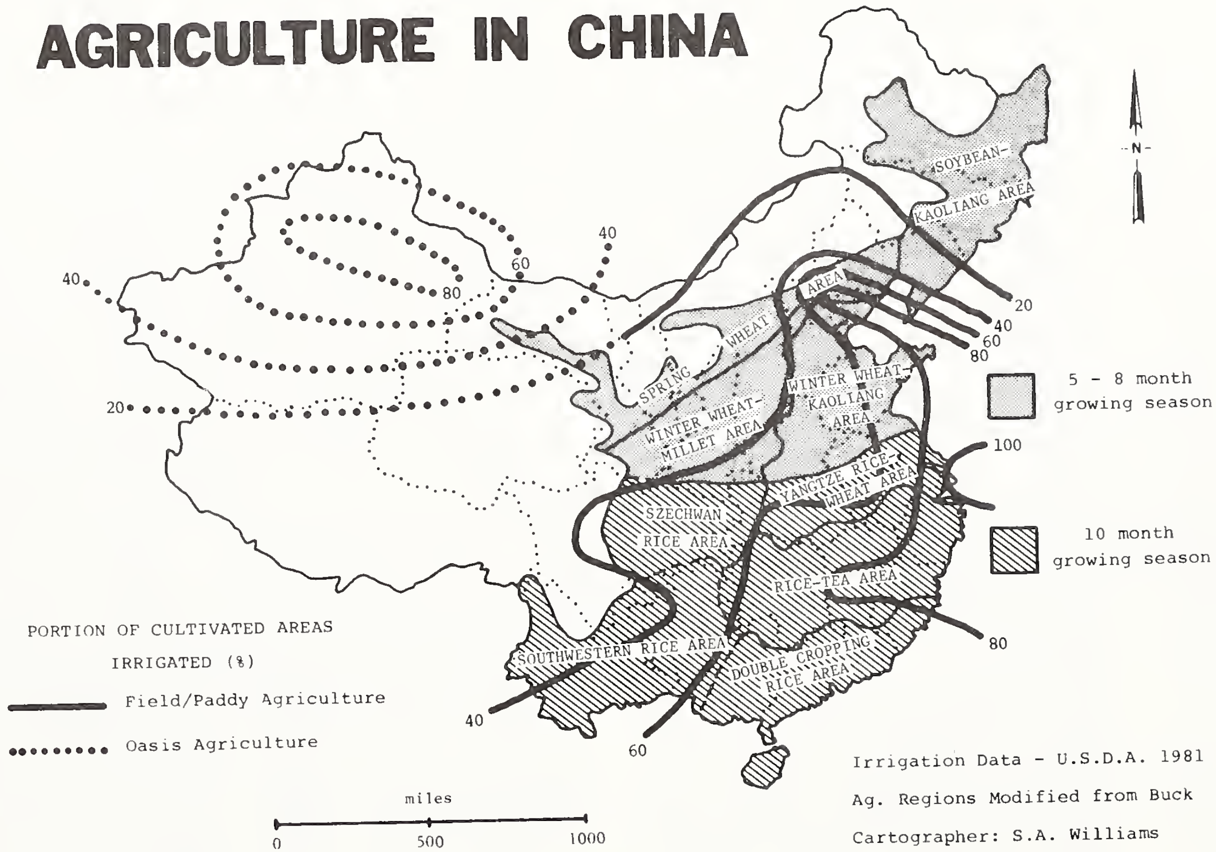
AGRICULTURE IN CHINA
SOYBEAN-
KAOLIANG AREA
SPRING
WHEAT
AREA
WINTER WHEAT-
MILLET AREA
WINTER WHEAT-
KAOLIANG
AREA
YANGTZE RICE-
WHEAT AREA
SZECHWAN
RICE AREA
RICE-TEA AREA
SOUTHWESTERN RICE AREA
DOUBLE CROPPING
RICE AREA
N
5 - 8 month
growing season
10 month
growing season
PORTION OF CULTIVATED AREAS
IRRIGATED (%)
Field/Paddy Agriculture
Oasis Agriculture
miles
0
500
1000
Irrigation Data - U.S.D.A. 1981
Ag. Regions Modified from Buck
Cartographer: S.A. Williams

Figure 1.

The Tsingling Divide, roughly the 34th parallel, separates the cold, dry, winter wheat regions of the north from the wet, rice-growing regions of the south. Extensive animal husbandry is only important in the north; intensive animal husbandry, specifically hogs, is dominant in the south. Railroads tie the north and south and the east and west of China together. The railroad system has greatly improved since the 1950's, i.e. new lines, new industrial spurs, and expanded railroad yards. Roads serve short-haul or farm-to-market functions. Although China's industry remains underdeveloped, the country is relatively well endowed with most minerals and its energy resources are more than adequate to support a major industrialization program.

AGRICULTURE AND FOOD SUPPLY

Chinese agriculture traditionally has performed three major economic functions: 1) supplying food to a very large internal population; 2) providing raw materials for the food and textile industries, and 3) earning foreign credits or cash through agricultural exports. Subject to acute population pressure on limited agricultural land, traditional Chinese agriculture was intensive and concentrated upon grain-vegetable crops which had high human food value yield. Agriculturalists provided the peoples of China with adequate food for survival in years without serious cultural or natural disruptions by sheer hard work and extreme attention to minute detail, rather than the application of scientific methods. Fertilizing materials were collected from every available source and soil productivity was maintained and enhanced. Every bit of cultivatible land was utilized and hillsides were terraced on an elaborate system. Field work began before dawn and terminated after dark during the growing season. Continuous liquid and solid manuring of plants prior to and at the time of maximum growth and development obviated the necessity of complex crop rotation patterns practiced elsewhere. In a country with so many people, so little capital, and so many poor, no waste was permissible; every scrap of grain was recovered, and straw and roots were carefully hoarded for winter fuel. Then, under the direction of Chairman Mao, the traditional agricultural system in China experienced a tremendous change. Confiscation, collectivization, and communization brought about peasant discontent and finally led to agricultural stagnation, induced by errors in data gathering, naive planning, paucity of capital investment, and lack of personal incentives.[5] The Communist Party leadership hoped the new problems in agriculture could be resolved by emotionalism and enthusiasm, but the innovations in agriculture had upset the peasant routine far too much for food production to be maintained (Figure 2).

THE 1959-61 PERIOD: CHAOS IN THE COUNTRYSIDE

Agriculture in China is highly socialized and organized to serve the interests of the state.[6] Organization of agriculture, in accordance with Marxist-Leninist-Maoist theories on agricultural collectivization, had achieved a very high level of socialization in the 1959-61 period through three major phases:

1) the land-draft animals-tools redistribution phase, implemented from 1949 through 1952;

2) the cooperative phase, during which there was a shift of land ownership from individuals to cooperatives and the development of the mutual assistance brigades, completed during the First Five Year Plan (1953-57), and

3) the transformation of cooperatives into communes phase, commencing in 1958; within a few months 98.2 percent of all rural households were communized.

Communization was a major step in the completion of agricultural collectivization and was the final step towards total state ownership. It also provided a base for rapid urban industrialization through the use of capital, facilities, and labor controlled by the communes. Mao Tse-tung declared, at the beginning of the Great Leap Forward Campaign of 1958, the policy of "walking on two legs" (developing urban industry and agriculture simultaneously) and the "eight-character constitution of agriculture."[7] The eight Chinese characters for the technical transformation of agriculture were: shui, water conservation; fei, fertilization; t'u, soil conservation; chung, seed selection; mi, dense planting; pao, plant protection; kung, tool improvement, and kuan, field management. Neither the "communization of agriculture," "walking on two legs," nor the "eight character constitution of agriculture" progressed as successfully as had been expected. Social disruption associated with the commune system and abuses associated with the zeal generated by the Great Leap Forward upset China's intricate traditional farming system. Peasant apathy and indifference, diversion of nearly two-fifths of the agricultural work force to non-agricultural activities, and unfavorable agricultural weather created an agricultural crisis of catastrophic proportions. Threatened with the first nation-wide famine in Chinese history, immediate action was taken by the government to conserve food, to import food, and to reduce the energy expended by the population; the problem, however, was where to direct famine relief for statistical data available was unreliable and meaningless.

DATA LIMITATIONS

Unlike the United States government and its agencies, China had not systematically implemented methods of identification, development, utilization, and dissemination of agricultural information internally. Routine information found in national yearbooks, statistical abstracts, and annual data reports were unavailable for China during the periods of internal adjustment and are difficult to secure today.[8] For decades most books or scientific data were published in limited quantity and restricted in dissemination. Statistical suppression became very severe in 1959, circulation of almost all relevant information ceased in 1960, and only in the late 1970's and early 1980's was a substantial quantity of useful statistics made available to western scholars in Hong Kong and elsewhere.

Quality of data during the first decade of communist rule was questionable. Deliberate falsification by local and regional statistical authorities up until 1959 was not the norm and establishment of the State Statistical Bureau produced a gradual improvement in the gathering and processing of

data. Statistical reliability, in years when more data was available prior to the 1959-61 famine and now, is undermined by the pressures on scientists, local officials, managers of enterprises, and local party members to fulfill and overfulfill assigned goals. Economic decentralization and the Great Leap Forward almost destroyed the statistical reporting services and reality gave way to published fictional dreams. Exaggerations extended to all segments of Chinese culture where reporting activities to the central government was necessary, and authorities distorted data when it suited their purposes. Along with what might be termed "statistical inflation" according to needs during phases of Chinese socialist development, language and cultural barriers are formidable within China and within nations that have interest in China's growth and development.

At this time there is information available in translation. For pure research and for spatial analysis, however, knowledge of this very difficult language is necessary. Few agricultural specialists and topical academic researchers in the United States, for example, are immersed in the history and culture of China as well in as the modern institutions of Chinese communism. Nevertheless, with the information available, with great data voids, and through personal field experience, it must be concluded that the investment in agricultural research within China is too low. State investment funds have been utilized primarily for capital construction, water related projects, and machine building; limited local funding has been invested in crop improvement and land reclamation.

UNDERINVESTMENT IN AGRICULTURAL RESEARCH: A PRELUDE TO FAMINE

Agricultural science and technology in communist China was aided initially by Soviet specialists until about 1960, then continued on a modest and sporadic scale by directives from the party and central government until a new appreciation for agricultural research emerged in the late 1970's. The general plan for a development of science and technology was patterned after the Soviet system. Shortly after the revolution, the Chinese Academy of Sciences was founded and the new organization focused much of its research activities in 16 research institutes. In the late 1950's, a state Scientific and Technical Commission directed most of the scientific and technological activities in China. Research and development institutes were administered, in general, by the Ministry of Agriculture. The amount of research and development in agriculture then and now is very small when compared to the United States or even to the Soviet Union. One of the long-term problems was the shortage of professionals to conduct research and direct development activities. Relatively little research is done at institutions of higher learning and the party initially attempted to maintain direct control of scientific and technical development in agriculture.

Figure 2. Underinvestment by the Chinese government in agricultural research has had an adverse effect upon food production, food processing, food storage and food delivery. Today, thrashing of wheat is still done by horse and roller in areas of China.

Figure 3. Agriculturalists provide the people of China with adequate food in years without serious cultural or natural disruptions by sheer hard work and extreme attention to minute detail, rather than application of modern scientific agricultural methods.

Since the revolution, the major fields of agricultural research have included plant genetics, tea culture, soil chemistry, plant protection, veterinary science, agricultural economics, animal husbandry, general agriculture, irrigation systems, agricultural mechanization, agricultural electrification, management, agricultural meteorology, pedology, pasture management, and forestry. A recent theme in agricultural research and technology has been technical transfer of ideas, methods, and innovations from foreign nations to China, if applicable to conditions existing in China. Concomitantly, China is implementing and supporting applied agricultural research more so than basic research at this stage in the nation's development. Scientific and technical accomplishments, on a modest scale, have generally exceeded the estimates of many non-Chinese observers, and have been attained in an atmosphere not at times conducive to research.

Present agricultural research and technical investment policies will require years and more capital outlays to overcome the disasterous effect of Chairman Mao's agricultural policies. The Chinese government, recognizing that it possesses one of the world's oldest and more efficient labor intensive agricultural systems and that it is faced with the problem of feeding more than one billion people, has stated repeatedly that agriculture is the foundation of the national economy and that all-around development of the rural sector is the key to the viability of the whole state.[9] State planners are deeply alarmed by the unrelenting pressure of population growth and industrial expansion on arable land. To the planners' terror, the country's cultivated land area has decreased in the past two decades while the country's population has soared from nearly 640 million to over one billion (Figure 3).

In 1957 cultivated area within China exceeded 270 million acres (112 million hectares); in 1977 the cultivated area had been reduced to about 240 million acres (99 million hectares). Industrial parks and urban sprawl claimed 75 million (30 million hectares) or so acres of cultivated land, but reclamation of nearly 45 million acres (19 million hectares) of semi-desert, steppe, and virgin land substantially reduced the overall cultivated land loss. China's agricultural planners reaped the bitter harvest of underinvestment in agricultural research and agriculture by whim. They have a mind-boggling task of safeguarding a limited and precarious food supply for a growing massive population. Poorly researched, improperly conceived, and ill planned large-scale reclamation projects have led to widespread destruction of vegetation, widespread loss of fertility, secondary salinization of large tracts of arable land, and widespread expansion of deserts. In most instances, blind reclamation has meant more agricultural and ecological problems than gains. Recommendations to reverse trends and to modernize Chinese agriculture include:

1. formulation of well thought out and well researched agricultural plans appropriate for existing Chinese culture and perceived future needs;

2. raising of the scientific, technical, and cultural level of all rural inhabitants;

3. introduction of appropriate scientific research and technical development in advance of implementation;

4. steady agricultural growth combined with maintenance of ecological balances;

5. total electrification of the countryside;

6. popularizing advances in agricultural technology;

7. practical application of past, present, and future proven agricultural research and technology, and

8. adoption of foreign technology when appropriate and when the initial investment is quickly returned in increased or improved production.

Population increase, a general rise in per capita income, and a greater use of material incentives will exert a steady demand-pressure on Chinese agriculture. Governmental response to these three demand-pressures is critical. If the government is unable to overcome decades of underinvestments in agricultural research and the mistakes made because of lack of research, the next major natural calamity or cultural calamity could produce a famine far more devastating than the 1959-61 famine.[10]

THE 1959-61 FAMINE

Misled by inaccurate agricultural statistics, the Chinese government announced in 1958 that the nation had doubled agricultural production in a single year; this permanent gain would enable one-third of the agricultural land to be taken out of cultivation.[11] Agriculturalists released from agricultural activities associated with this land would be transferred to socially productive tasks such as dam building and smelting steel in backyard furnaces.[12] The decision to reduce the area sown to food crops throughout the entire country had an adverse effect upon the harvest.[13] Food shortages, serious in late 1959, reached a critical low during April and May of 1961, just prior to that year's harvest.[14] The central government sponsored a national campaign to collect wild plants to be used as food substitutes, set up workshps to make "famine foods," and urged citizens to eat more vegetables and less grain. Stringent food rationing was strictly enforced and rationed basic food per capita was gradually reduced. Twenty million urban residents were ordered into the countryside to ease the food shortages in cities and grain imports were increaesd from 2.6 million metric tons in 1960/61 to 5.8 million metric tons in 1961/62. Even military rations were reduced. The food crisis was not only quantitative (amount of food available) but also qualitative (type of food available). Per capita caloric intake prior to this food crisis ranged between 2,000 and 2,200 calories per day; the ten to 20 percent caloric reduction during this period had a deleterious effect. Domestic food supplies were able to provide less than 1,800 calories per day and imports of grains and sugars raised caloric intake to approximatley 1,900 calories (Table 1). The vastly improved internal transportation system permitted

shipments of food to areas of acute food deficiencies, but food nation-wide was scarce. Government political retrenchment and concessions to agriculturalists were swift, but the action was too late to immediately temper the problems facing the country. There were food riots, reports of workers collapsing at their jobs from starvation, reduced work loads and reduced work hours, and general preoccupation with food. Special work units were announced and vast numbers of peasant farmers were released from brigade supervision and assigned to production teams which reverted to more traditional farming and more traditional rural activities.

As might be expected, the deterioration in food supplies brought about a rising incidence of nutrition diseases. Food rations were set at a nation-wide inadequate level and the nutritive quality of the rationed diet was unsatisfactory. Those individuals with funds could purchase quality

Table 1
CHINA--FOOD BALANCE 1960-61

	Gross Domestic Production	Non-Food Uses	Net	Food Supplies	
	million metric tons			Kilos per head	Calories per head per day
Grains	140.0	46.0	94.0	145.0	1,430
Potatoes	40.0	17.0	23.0	35.0	90
Pulses	10.0	6.8	3.2	5.0	50
Soya Beans	8.0	4.8	3.2	5.0	50
Sugar	1.5	0.2	1.3	2.0	20
Fruit & Vegetables	80.0	40.0	40.0	60.0	50
Meat & Poultry	5.7	0.5	5.2	8.0	65
Eggs & Fish	5.0	1.1	3.9	6.0	15
Fats & Oils	3.0	0.4	2.6	4.0	90
Total Domestic Imports	---	---	---	---	1,860
Grains	2.5	0.5	2.0	3.0	30
Sugar	0.5	---	0.5	1.0	10
Grand Total	---	---	---	---	1,900

Source: "Communist China's Agricultural Calamities," The China Quarterly, No. 6, April-June, 1961, 75.

foods from the black market and improve their basic ration. Malnutrition and undernutrition caused widespread night-blindness, famine edema, famine diarrhea, liver disorders, tuberculosis, amenorrhea, beriberi, and a general rise in mortality.[15] Famine edema varied from 20 percent in some area to 60 percent in others. Hospitals were over-crowded with people seeking medical assistance and infectious hepatitis was transmitted to medical personnel. There was a marked increase in numbers of stillborn babies. Lower caloric intake and the absence of important elements in most diets reduced resistance to disease and resulted in widespread common illnesses, slower recovery, and higher fatality than normally would have prevailed. At minimum 25,200,000 deficits in births occurred, at a minimum 6,800,000 deaths, and at minimum natural increase declined 32,000,000.[16] The Chinese Famine of 1959-61 was one of the greatest tragedies that occurred in the last half of the twentieth century (Table 2).

Table 2
China: 1950-63
Demographic Factors

Year	Birth Rate (%)	Death Rate (%)	Natural Increase (%)	Population
1950	3.7	1.7	2.0	558,000,000
1951	3.7	1.7	2.0	570,000,000
1952	3.7	1.6	2.1	581,000,000
1953[1]	3.7	1.4	2.3	593,000,000
1954[1]	3.3	1.3	2.0	608,000,000
1955[1]	3.3	1.2	2.1	620,000,000
1956[1]	3.2	1.1	2.1	634,000,000
1957[1]	3.4	1.1	2.3	647,000,000[2]
1958	3.1	1.5	1.6	657,000,000
1959[1]	2.5	1.5	1.0	664,000,000
1960	2.0	2.0	0.0	664,000,000
1961[1]	1.8	1.4	0.4	667,000,000
1962[1]	3.7	1.0	2.7	685,000,000
1963[1]	4.4	1.0	3.4	708,000,000

Births: 1959-61

Year	Computed[3]	Reported	Losses
1959	21,900,000	16,600,000	-5,300,000
1960	22,400,000	13,300,000	-9,100,000
1961	22,800,000	12,000,000	-10,800,000
	67,100,000	41,900,000	-25,200,000

Deaths: 1959-61

Year	Computed[4]	Reported	Increase
1959	8,400,000	10,000,000	+1,600,000
1960	8,600,000	13,300,000	+4,700,000
1961	8,800,000	9,300,000	+500,000
	25,800,000	32,600,000	+6,800,000

Natural Increase: 1959-61

Year	Computed[5]	Reported	Losses
1959	13,500,000	6,600,000	-6,900,000
1960	13,800,000	0,000,000	-13,800,000
1961	14,100,000	2,700,000	-11,400,000
	41,400,000	9,300,000	-32,100,000

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4. Using 1957 as the base year, computed by employing the 1954-58 five year average of 0.0125% per year.

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Factors Contributing to the Food Crisis

Physical

Chinese communist government officials blame devastating natural calamities, particularly floods, drought, and insect pests, as the primary factor for three years of consecutive crop failures -- 1959, 1960, and 1961.[17] A serious drought, similar to the six great droughts that triggered massive internal problems in the 1928-44 period, encompassed 17 provinces and autonomous regions in the Yellow and Yangtze River basins reducing yields on 22.9 million hectares of cropland in 1959. Concomitantly, torrential rains in extreme north-central and extreme south China inundated 395,000 hectares, destroyed 200,000 houses, damaged 28,000 irrigation projects and injured or killed two million people. In 1960, while drought affected agricultural yields on more than half the arable land in China, or approximately 60 million hectares, moisture stress was severe on 20-27 million hectares and some fields produced no crop. Similar natural calamities prevailed in 1961. Droughts again reduced yields but in a different agricultural region--west-central China; typhoons and floods disrupted agricultural activities in the southwestern provinces. Food production was reduced on 60 million of China's total 110 million hectares of cultivated land. Weather proved to be less of a problem in 1962 and food production increased. Chou En-lai told Edgar Snow, the American journalist, that 1959 and 1960 had been the years of the the most serious natural calamities China had encountered in the twentieth century. This statement by Chou En-lai is not in accord with claims made repeatedly in the People's Daily a few years earlier and advanced by Adler in 1957. Adler contended that in China:

> Natural calamities are no longer unmitigated catastrophes, "acts of God" bringing famines, epidemics and enormous loss of life in their train. Negatively, the Government remits all the obligations of the stricken area. Positively, it institutes large-scale relief, mobilising its food reserves -- accumulated not only from agricultural tax yields but also from its heavy purchases of food -- and all available transport facilities to send supplies immediately to focal points for local distribution. Wherever possible, production of substitute crops is started to reduce the length of the emergency. To tide over the longer run efforts of crop failures, it advances seed to the destitute to enable them to recommence production as soon as conditions permit. On a humanitarian level no contrast could be sharper than that between the helplessness of the old regime when confronted with natural disasters and the planned provision of rapid relief which has increasingly become standard practice. It is the difference between the "nasty, brutish" state of anarchy and social order.[18]

He also stated that, when China was governed by the Kuomintang, many natural disasters were transformed into famines by official policies. Nor is Chou En-lai's statement in accord with Mung's pronouncement that, "Although serious drought occurred in 1959 and 1960, the unit-area output of grain was still increased."[19]

Cultural

The Communist Party leadership tended to believe that the elimination of peasant small holdings and the development of large-scale farming would bring about a massive increase in food production. Almost as soon as land redistribution had been completed in 1952, there was a systematic introduction of cooperation techniques via "mutual aid teams" and then total collectivization by 1957. To Party theoreticians, the collective farm was seen as a transitional stage or another step forward from individual ownership of the land to group ownership -- a higher stage of socialization.[20] Transformation of cooperative farms into people's communes began in 1958 and was completed in less than a year. Communes were the major step in the completion of agricultural socialization and the final step from individual land ownership, group land ownership, to total state land ownership. Communes were envisioned as comprehensive social institutions which combined industrial, agricultural, business, educational, military, and political functions into an organic whole. They were also envisioned as multi-functional economic institutions involved in or housing industrial, food processing, forestry, animal husbandry, and fishing enterprises. Communes were to be large in scale as well as scope. After communization, the average commune in China was composed of 5,000 farming families and about 5,000 hectares of farmland; the average commune was an amalgam of 30 former agricultural producers' cooperatives. Commune production goals were required to be in accord and to follow the unified planning of the central government. The primary duty of the commune was to guarantee the fulfillment of state assigned tasks. A few months after the inception of the campaign to communize China's agriculture, the Central Committee of the Communist Party passed a resolution criticizing overzealous cadres, excessive centralization,and recommended distribution of income on the basis of work. It was only when the agricultural disaster of 1959 was followed by a second monumental agricultural setback in 1960, that the Party began to implement serious and drastic measures to check the rapidly deteriorating internal food situation. Dutt noted:

> The notion of vast peasant armies moving up and down the land to perform great feats of labour to "transform nature" and of the peasant alternating for different kinds of jobs and skills, becoming both a worker and a peasant, not to speak of being a student, soldier and technician all lumped into one, played havoc with agricultural production. The changes were too great, too sudden and too startling. Not only did the peasant lose his moorings, but the whole system of agricultural production became dislocated. It had to be put back into shape, and a thorough reorganization effected before the situation could return to normal.[21]

Acknowledging privately that their policies had played a part in bringing the country to famine and in seriously undermining the traditional Chinese work ethic, the Party took measures to restore peasant incentive in

agricultural production by restoring private plots, private ownership of livestock, and "free" marketing of privately produced food items; communal mess halls and schemes for the mobilization of rural labor were abandoned and construction and special production units which had proliferated during the Great Leap Forward were discontinued. Organizational forms of agricultural production, food consumption in rural areas, and food distribution reverted to those of the 1955-56 collectivization state. Socialism retreated in rural areas in response to pressing critical national food needs.[22]

CONCLUSIONS

Agriculture is China's most important industry, supplying materials for three basic human needs -- food, clothing, and shelter. Chinese agriculture is basically of the intensive subsistence type where large amounts of human labor is substituted for capital. Agricultural research in China has not enjoyed continuous political support and adequate stable funding to develop more efficient and more economical ways of producing and processing agricultural products. As a result, there has been uneven development in agriculture, and a famine. Developments in agriculture since the revolution were influenced by both weather problems and the impact of substantial changes in economic policies for rural dwellers. Policy measures and the changed structure of work incentives affected acreage sown and yields. Current governmental quest for higher agricultural productivity has led to a change in basic socialist agricultural tenents and management experiments that the government had hitherto extended only to industry. Even if food production increases substantially in coming years, the increase in supply could be offset by new demand pressures stemming from a commitment to higher living standards. Greater agricultural investments are necessary to improve crop-growing methods, to improve livestock, and to invent new farm equipment for the specific needs of rural China. Underinvestment in agricultural research, in a nation with China's problems, is a precursor to famine.

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PUBLIC SUPPORT FOR AGRICULTURAL SCIENCE:

EVOLUTION AND TRENDS

by

JAMES H. SHIDELER

American agriculture has entered a critical time. Anxious public interest attaches to policy issues about food costs, productivity, the farm depression, farm exports (including grains for Russia), water for irrigation, soil erosion, pesticides, energy for agriculture, and farm structure. These and other concerns call for resolution. How we got here can be instructive. The shape of our agriculture has been largely molded by the applications of science spurred on by economic forces. Projections for the future will have to take into account the ability of agricultural science, both public and private, to meet dramatically changing production and consumption requirements.

Before 1900 science applicable to agriculture and encouragement for expanding it came to be accepted in public policy. During the 19th century there converged an enlightened regard for science with its ability to unlock the mysteries of nature and a warm respect for agriculture and farmers as a basic part of the democratic society. These are two of America's great faiths. In addition, there arose some dimly perceived appreciation of agriculture as a source of economic growth and an acceptance of government's capability to act positively to advance the national interest. A growing spirit of public support for agricultural science showed up in a familiar succession of actions: George Washington proposed a national board of agriculture; the early Patent Office accumulated and publicized agricultural information; the U.S. Department of Agriculture and the Morrill Act agricultural colleges were born to disseminate what was known and to expand knowledge by their own inquiries; the states created boards of agriculture and the early experiment stations, and the landmark Hatch Act of 1887 began a national system of state agricultural experiment stations with federal subsidies and gentle supervision. (The Hatch Act centennial is not far ahead.)[1]

By 1900 there was in place and fixed in public policy a promising system of scientific research and educational institutions jointly sponsored and funded by the state and national governments. To keep alive the policy of public support there was a vigorously effective pressure group--the administrators of the system who organized in 1887 as the Association of American Agricultural Colleges and Experiment Stations (now the National Association of State Universities and Land-Grant Colleges).

Despite an already elaborate institutional system for research in the agricultural sciences, the process of building a body of applicable science faltered. Hatch Act funds for research were sometimes "embezzled" locally for other purposes. The agricultural colleges had only a small store of science to teach, few students to teach it to, and few qualified teachers to teach it. Understaffed experiment stations were burdened with trivial and shallow analysis of soil, seed, feed, and fertilizer, harassed by farmers wanting immediate answers for particular problems, and starved for funds by chintzy legislators.

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Still, here was the beginning of a prosperous age for agricultural science, a time when publicly supported scientific research was mostly agricultural science and nearly all agricultural science was public science.[2] It was a time of increasingly generous public funding for agricultural research. It was a time of marvelous advances in scientific knowledge like the rediscovery of Mendelism in 1900 and the birth of genetics as a science. Ambitious experiment station scientists hungered for and gained substantial freedom of inquiry, professional recognition, and advancement by and among their peers, and association of kindred minds through the organization of discrete disciplines and professional societies.

Early in the twentieth century the Adams Act (1906) was another landmark which forecasted much of what was ahead for agricultural science. Like the Hatch Act it was rooted in local interest by the flow of doubled federal money to the states for the experiment stations and tied into a national system through the U.S. Department of Agriculture. And, like the Hatch Act, it was conceived by the leaders of the agricultural science establishment organized as a powerful political interest group. Dean W. A. Henry of Wisconsin, his friend, Congressman H. C. Adams, and A. C. True of the USDA Office of Experiment Stations were the principal artists. The bill was drafted, the agricultural college and experiment station mafia rallied round and mobilized their friendly farm journals and sympathetic politicians. Congress and the public in that Progressive era were receptive to the promise of productivity and efficiency through science. What was new was a directive limiting the augmented support to "original" inquiries or pure research and Congressman Adam's persuasive argument that investment in research had a multiplier effect in the economy.[3] In several respects the Adams Act represented a coming of age for agricultural science. Public purse strings were loosened. The Act demonstrated the political influence of organized agricultural science. It also put experimentation on a higher level by freeing scientists from immediate problem-focused inquiries to pursue basic research promising in the long run a more productive science. Experiment station scientists were now more answerable to advancement of knowledge than to the farmer constituency.

Even by this early time scientific agriculture had more to offer farmers than was being diffused and practiced. News of improved techniques through the pages of farm journals went only so far. (Note Schlebecker's paper on this program). The millions of copies, literally millions, of USDA and experiment station bulletins mailed out lit fewer fires in the minds of farmers than fires in the kitchen range. Farmers' Institutes, demonstration trains, and fairs were not moving a dispersed agriculture forward in step with a modernizing technological society.[4] The Smith-Lever Act in 1914, which created a nation-wide extension service with farm advisers working directly with farmers, was a public policy consequence of an accumulating body of applicable science. With county agents standing between the experiment station scientist and the farmers, the scientist had less responsibility for dissemination of information while extension filtered back to the station the questions facing farmers. In time, extension would take on scientific researches of its own.

From these foundations there was built a huge and complicated structure of food and agricultural research.[5] Secretary of Agriculture "Tama Jim" Wilson was especially adept at prying loose from Congress generous funding for scientific work in his department.[6] In the states sharp political operators like Eugene Hilgard in California and W. A. Henry in Wisconsin kept the money, the life blood, flowing.[7] The multiplier effect argument for research was picked up by Dean Eugene Davenport who told the Illinois legislature that the Babcock butterfat test, a product of Wisconsin, was worth more to that state's dairymen than all the costs of the University of Wisconsin, the college of agriculture, and the experiment station since their founding.[8]

In later years federal support was extended with the Purnell Act of 1925, the elevation in 1934 of the Beltsville farm (purchased in 1910) to a Research Center, the 1935 Bankhead-Jones Act provision for regional research programs, the 1938 Triple A funding for USDA regional research laboratories, the forward-looking Research and Marketing Act of 1946, and the Hatch Act revision in 1955. All of these encouraged an impressive proliferation and swelling of institutions employing scientists by the thousands. Here are lessons in scientific bureaucracy.[9] On top of this an outpouring of federal funds for supporting other kinds of scientific inquiries was set off by World War II. The National Science Foundation, National Institutes of Health, national defense, and space agencies sponsored researches which the agricultural college and experiment station scientists could undertake. While agriculture's share of the total national research budget shrank, the volume of agricultural science funding grew handsomely, in recent years somewhere around a billion dollars annually. At the same time the farm supply and processing industries found it advantageous to place research grants at public institutions. These have amounted to as much as 10 percent of the experiment station budgets.

In those flush go-go years of agricultural science the blurring of pure science and applied technology, the blurring of distinctions between agricultural science and science, the blurring of lines between public and private research, and the social consequences of industrialized agriculture were all blithely disregarded. It was enough that agricultural science was pursuing the unassailably honorable purpose of finding out how to grow with less labor two blades of grass or two ears of corn where one grew before and, at the same time, expanding man's fund of knowledge.

Twentieth-century America, by chance rather than by intention, came to possess a unique interlocking system of scientific research which was marvelously productive of a body of knowledge that resulted in amazing gains in agricultural productivity as well as in useful knowledge for nonfarm sectors. The agricultural colleges and stations had another role: to educate the generations of technicians and professionals needed for American modernization, to inform a citizenry receptive to technological innovation, and to train more scientists to staff growing research institutions and to carry on the expansion of knowledge.

To be sure, atrocity stories of interference with the work of researchers speckle the history. Rustic legislators and trustees interposed their fundamentalist prejudices and dairy interests applied pressures against inquiries into the nutritive value of oleomargarine. Public research institutions were a species of public property open to trespass by the curious, by farmers wanting attention, even by visitors who robbed fruit from experimental plots.[10] Nonetheless, creative scientists enjoyed an unparalleled freedom for their inquiries, which allowed the best minds to do their work. Science is fruitful as it is free from restraint. Don K. Price, speaking generally, says "the American system gives scientists in government a freedom and influence unmatched in other countries."[11] Public science must be detached, maintaining a respectful distance between the scientist and the public. USDA supervision of Hatch Act subsidies, weak as it has been, was a handy shield for station administrators against state political interference. Critical observers of the agricultural science system deplore the lack of a comprehensive and articulated guiding policy as well as the effects of internal duplications, competition, and slippage. Agrarian activist critics come down hard on the neglect of the social consequences of applied technology, even charging complicity of public agricultural science and corporate agribusiness.[12]

A lofty view, however, must acknowledge the national gains of scientific agriculture (what this symposium is all about). We are inclined to measure success quantitatively but, in recent years, the statistics of production increases of one day are obsolete the next and useful only in plotting an upward curve. Gross volume of agricultural production swelled 179 percent from 1910 to 1979. Production per acre, production per man, and animal weight gain per unit of feed, eggs per hen, butterfat per cow--all registered magnificent jumps. We point with pride to the number of nonfarmers supplied by each farm worker--seven in 1910 and 65 in 1980.[13] We also celebrate the five percent of our national workforce employed in farming compared to the USSR with about 32 percent, and Asia with 57 percent. Science plus the pull of the market transformed American agriculture from a way of life for about 38 percent of the population in 1900 to a high-tech industry employing about 2.5 percent of the population in 1982--or, more realistically, about one percent if there are subtracted those so-called farms that are not really farms.[14]

A critical stage in the history of public policy for agriculture and agricultural science was the Progressive Era of the early twentieth century. Progressive Americans were concerned, even alarmed, by the problems cast up by a rapidly industrializing and urbanizing nation and the disorderly agrarian agitations of the recent Populist movement. Knowledge, science, and efficiency were watchwords for progressives more confident than we that predicaments were solvable. The evils of city life needed to be balanced by a wholesome and satisfied farm population, hence the Country Life Commission of 1908. The frontier of free or easily acquired land and for new farms was closing. Frederick Jackson Turner's views on the end of the frontier were getting around outside the circles of history professors. It seemed to stand to reason that the end of new croppable land meant an end to the

expanding volume of agricultural production. President Theodore Roosevelt, alert to such matters, declared that "with our increasing population the time is not far distant when the problem of supplying our people with food will become pressing. The possible additions to our arable area are not great, and it will become necessary to obtain much larger crops from the land."[15]

What Wayne Rasmussen calls America's first agricultural revolution, which shifted power requirements from human muscles to horsepower, had run its course. Horsepowered farm machinery had gone as far as it could go.[16] There were steam engines that gave a hint of promise for mechanical power but there were then severe mechanical and economic limits upon the steam traction engine or land locomotive. Steampower on farms had topped out. As a matter of fact, the rate of crop production increases was leveling off. This was a source of alarm to progressive Gifford Pinchot: "Agriculture ... has reached one of the chief turning points in its history. The frontier method of extensive cultivation is past, and intensive cultivation is about to take its place. This change, unfortunately, is accompanied by a most serious decline of production. Thus, in the last census period, while population increased 21 percent, the production of agricultural crops increased by 10 percent. The decrease was accompanied by an enormous rise in the cost of living."[17] Exports declined as American consumers ate into the surplus. Wheat exports fell 46 percent between 1903 and 1908 while corn exports dropped 30 percent.

A plateau of technological innovation had been reached. There was no new breakthrough in sight. Solemn magazine articles announced: "That we have reached our limit of agricultural production under methods practiced in the past is generally admitted. The public lands that are suitable to farming have all been occupied, no revolutionary labor-saving machinery is likely to be invented."[18] The census of 1900 and 1910 showed a population increase from 76 million to 92.4 million, an increase of 21.5 percent. Immigration at the rate of about a million a year plus natural population growth projected domestic market demands that would exceed supply in about 20 years. (Twenty years used to be the favored time for predicted disaster). James J. Hill, the railroad tycoon, attracted notice by predicting in Malthusian fashion that Americans would go to bed hungry within 20 years unless steps were taken to increase agricultural production. What he was really referring to was an improvement of techniques and the development of new agricultural land in the region served by his Great Northern and Northern Pacific railroads. Even writers on rural education cast their work in a context of crisis: "When the farmers stop producing an abundant surplus our growing millions face not only lowered standards of living, but in many cases actual want and starvation. When the harvests cease to be abundant the fires of our national life . . . begin to burn low, the productive powers of the nation are checked--the entire economic and social organism suffers a kind of paralysis."[19] The shrinking food supply resulted in advancing costs to consumers. Market basket prices were up 80 percent from 1896 to 1912. The high cost of living, familiarly known as "HCL," set off visible public restlessness.

The United States, having recently acquired an overseas empire, was extending its horizons and trying its wings as a fledgling world power. Americans were learning that commerce, food, and raw materials as well as navies, armies, and factories were underpinnings of national strength and chips in the game of international power politics. These facts were soon to be reinforced by World War I with its critical food shortages. Food had become a strategic material.

That agriculture must be assisted became accepted as a Progressive cause. The concerned Progressives were mainly urbanites; the real farmers were less interested--they were not doing so badly. Farm prices and land values moved up handsomely. Land values were up 118 percent from 1900 to 1910 and prices of farm products were up 89 percent.[20] Some historians called this period agriculture's "Golden Age" and 1910 to 1914 was eventually to be used as the pre-war normal parity base period.

Politicians, farm journals, federal agencies, and state institutions showed much interest in intensive farming, conserving soil fertility, checking erosion, reclamation, and rural social uplift to make farming attractive. It was said that every 40-cent bushel of corn carried away with it 18 cents worth of soil fertility. A USDA publication put the matter plainly: "Now, when the period of settlement is practically past, we find ourselves confronted with increased demands for food, which must be met by soils that have been depleted of much of their yielding power. This is an important factor in the recent increase in the cost of food."[21]

It was at this time that a spate of national legislation sought to modernize agriculture. Standing out were the Adams Act, the Smith-Lever Act, augmented appropriations for the USDA, the parcel post, federal highways, the Federal Farm Loan Act, Smith-Hughes Act, licensed warehouses, grain and cotton standards, a Bureau of Markets, an Agricultural Organization Service, and home economics work. Woodrow Wilson's administration brought much of this to completion. Wilson in addressing the U.S. Chamber of Commerce in 1915 said: "Has it occurred to you, I wonder, that . . . there is a shortage of food in the world now. . . . It is necessary that our lands should yield more per acre than they do now. . . . And the methods of our farmers must feed upon scientific information. . . ."[22] In these years public policy support for agricultural science and its agencies was matured and fixed. Agricultural science institutions became a self-perpetuating and swelling establishment, a small price to pay for the agricultural productivity and national economic growth that was generated.

Now, however, the concerns and alarms of 70 and 80 years ago have reappeared. The upward curve of agricultural productivity has again leveled off. Per acre yields peaked in 1972. We seem to have entered a period of limits.[23] The costs of food to consumers have moved up distressfully. Domestic demand is growing with a new wave of immigration (about a million a year, like at the beginning of the century). A sharpened awareness of American involvement in providing food for hungry world populations, plus exports for sale, put pressure upon our capacity to

produce. Exports for sale have become critical in meeting an unfavorable balance of trade. (This is especially interesting as the value of agricultural exports in recent years has approximated the value of oil imports).

American food as a diplomatic weapon appeals to foreign-policy makers when other resources are weak. Secretary Butz could say that "food is now one of the principal tools in our negotiating kit" and "agriculture now commands . . . a strategic position." Other nations may have Petro-power, but we have Agri-power. . . .[24] Embargoes are a useful way to show American resolve. "Food Power" in diplomacy, however, may not be all that persuasive when choking export flow forces supply to back up, cutting prices to producers and setting off cries of pain from an important constituency.

Dangers and limits to further production increases are staple fare of the news media. A General Accounting Office study released in February 1982 made headlines by warning that the food production system "is threatened by growing scarcity of basic resources."[25] Scare stories of horrendous soil erosion come out of the Northwest's Palouse country. And, in Iowa, it is said that farmers lose two bushels of soil for every bushel of corn they grow. Preservation of cropland from real estate developments and other diversions has become a cause. Estimates of land lost to farming are as high as 3 million acres a year.[26] Competition for supplies and depletion of water resources for irrigation are intense issues. Ascending costs of fuel plus inflating prices of other farm inputs determine the choices of farm managers more concerned with balance sheets than gross volume. There are economic limits.

Not yet at the level of intense public concern is appreciation that agricultural productivity is grounded upon applied technology produced by scientific research. No backlog of unapplied technology promising new production records exists. In 1975 the National Academy of Science concluded that a breakthrough in agricultural science comparable to the development of hybrid corn or DDT was not foreseeable within 10 to 20 years.[27] If there is to be another leap forward in agricultural productivity like that which made the "Science Power" revolution during the 1950's and 1960's it will have to come from the research laboratories. It could be, however, that the gains in productivity from 1950 to 1970 marked a unique stage in agricultural history that is now passing. Perhaps merely maintaining those gains in the face of declining resources of soil, water, and energy will come to be regarded as a major agricultural science achievement. Hard figures are elusive. There appears to have been an actual decline in public funding for agricultural science institutions as state and federal budgets are tightened.[28] Even steady-state research appropriations are diminished by inflation. And experiment station budgets have had to cope with demands for a share to be devoted to social and economic research.

While there are similarities between the public concern about agriculture during the Progressive Era and in our own time, a parallel is complicated by new issues. The farming population (and presumably farm voting power), which in 1900 was about 38 percent of the total, has shrunk to about 2.5 percent at present. That is a substantial loss of political influence. Protection for agrarian interests was further pared with the elimination of rural over-representation in legislatures by the one-man, one-vote decisions of the U.S. Supreme Court in the early 1960's. Anachronistic disproportionate rural weight in electoral districting could not last in an industrialized nation. The interests of farmers all together no longer command obedience. Not long ago Secretary Bergland said, "I can't count on 35 votes in the House of Representatives."[29] Agricultural specialization by commodity and region fragmented the voice of agriculture into rival interest groups. There is no longer a single agricultural interest even about science. Precedence has had to go to such peanut politics as that of Georgia's Senator Russell.[30] Retarding the downward slide in agriculture's political power has been a regrouping of farmers into muscular interest groups capable of influencing support for agricultural research along particular lines. Moreover, not to be overlooked as a source of political support for agriculture is residual public good will toward an image of farmers as wholesome and fundamental producers. Food has always had emotional additives, even today when consumers are very distant from the source.

Coming forward in recent years to complicate the mission of agricultural science are dissenters who ask "public research for whom?" It is plain enough that scientific research produced new technologies more useful to larger farming enterprises than to smaller ones. Adoption of new technologies involves risks and capital so the diffusion is greatest among those enterprises that are more economically productive. Agriculture, like other businesses, is profit-motivated and pressures of the economic system for cost saving and volume expansion made farmers seize upon the new technologies. Smaller and weaker commercial enterprises found themselves at a disadvantage and went out of business.

The farm crisis of 1982 is in its final shakeout, despite a new rise in the nonmetropolitan population with its part-time farmers subsidizing the business with low labor and managerial return, hobby farmers, and country residences that might be classed as farms but aren't. (I had one once. The inputs were heavy, the output was mainly non-economic. It was not a farm). It can be argued that high-tech agribusiness has benefited from farmers and consumers generally. Not so long ago the farm problem was seen by economists as excess capacity and surplus farmers who would be better off elsewhere. I can believe that sharecroppers from rural slums are not worse off even on welfare in urban ghettos. From the very beginning the experiment stations tilted toward those larger, successful, more vocal, more receptive, more publicly influential agricultural interests. Administrators and scientists prospered as they tended to concentrate on projects that served the clientele groups providing support. What James Hightower and Wendell Berry, among others, are really protesting is an economic system

mindful of narrow business interests. Nevertheless, the agricultural science establishment has lately had to recognize other interests. Environmentalists, nutritionists, consumers, and farm laborers are worried about the sociocultural consequences of newly devised technologies. They cannot be dismissed casually.[31]

Another new complication is the rise of private agricultural research. Until World War II nearly all scientific research for agriculture was publicly funded. There were some individual farmers concerned with inquiry and improvement. Agricultural machine companies devised and improved mowers, reapers, threshers, and tractors. Fertilizer, feed, and pesticide companies did some research of their own and funded some research in the experiment stations. Hybrid corn seed firms went beyond the work of the public scientists to develop a commercial product. Private agricultural research has gone a long way since Secretary Henry A. Wallace in 1935 said "scientific research in the industrial field can be supported by private funds, but in agriculture it is either done by the use of State or Federal funds or it is not done at all."[32] Agriculture's industrialization multiplied opportunity for private research and development because technological innovations had dollar value. Industries producing farm machinery, seeds, pesticides, drugs, and processing equipment could restrict the diffusion of their innovations and hold the gains for themselves. Investment in research and development paid off in grand fashion. Private research expenditures swelled immensely until today at about a billion dollars a year it may even exceed all the public funding of agricultural science.[33]

Proprietary research is not without its public connections. Industrial research is a tax-deductible expense and, thus, indirectly supported by the taxpayer. Private agricultural science feeds upon the knowledge discovered in public laboratories. And the public interest is interposed as technologies bear upon the environment and public health. The distinction between public and private agricultural research became blurred as private interests granted funding to experiment stations for particular inquiries. While the findings were in the public domain and may have added to the store of knowledge, the benefits were narrower and the public agencies' accommodation toward agribusiness tilted more steeply. Public science must be open. Private science profits from control. When the boundaries are blurred there are liable to be conflicts of interest.

To be sure, the role of the experiment station was ambivalent. As a public institution it served immediate farmer interests but the scientists worked hard to detach themselves from such pressures. The image of the experiment station as an annex of the ivory tower is in danger. When agricultural science and technology acquire monetary value public researchers are tempted to capitalize their inside knowledge. As John Muir said in a different context, "nothing dollarable is safe." Conflicts of interest occasionally have come to public attention as researchers and administrators were seen to be connected to private operations as consultants, officers, moonlight

employees, stockholders, and even producers. In recent days the monetary potential of recombinant DNA technology applicable to agriculture has precipitated a crisis for administrators of public science. (This is especially so at my own institution where there are newly devised and complicated procedures for disclosure of faculty and staff involvement with private industry). More distinct guidelines and rules than were once thought necessary must maintain the separate character of public research and private interests.[34] Confidence in and support for agricultural science will be challenged if public researchers are observed exploiting their public work for personal gain. Public research in the sciences related to agriculture with results in the public domain cannot be displaced by proprietary investigations. Fundamental inquiries where there is no clearly visible monetary payoff, where private research won't or can't or shouldn't go, remain the field for publicly supported science.

Right now there is concern about declining productivity in agriculture as well as industry. The only way to turn it around is by public research. Because of the time necessary to work out the basic research to develop and test applications and to make them available, continuous support is required to keep the progress moving. Among the continuing business on the agricultural science agenda are multiple birthing of livestock, nitrogen-capturing and self-fertilizing crop plants, enhanced photosynthesis, perennial grains, bio-regulators, clonal propagation by tissue culture, biological and cultural pest control, and crops for saline or brackish water.

The present administration's cultural revolution threatening deep cuts in support for science ill serves the national welfare. Back in 1905, Whitman Jordan speaking for the state experiment stations in hearings on the Adams bill declared with confidence that "we will take all the money we can get, and we can use it well."[35]

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ECONOMIC BENEFITS FROM RESEARCH

by

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The pioneering work of T. W. Schultz[1] and Zvi Griliches [2] at the University of Chicago in the 1950's established the basis for what has now become a significant body of studies of the economic benefits from agricultural research. In a recent review paper Norton and Davis [3] discussed recent manuscripts in the field. A large number of studies report estimates of benefits from research programs in the United States and elsewhere. Virtually all of these estimates show that the benefits from research are large relative to the costs of conducting research.

Yet today, agricultural research in the United States is receiving heavy criticism. Furthermore, spending on agricultural research by federal agencies has been declining in real terms over the past 15 years. State spending on research has risen slightly but combined state and federal spending as a share of the value of agricultural product, has fallen by 30 percent or so since 1960. At the same time indications are that spending on research relevant to the agricultural sector by private firms has risen significantly over the past two decades.

Why is it that of all the publicly funded research programs in the United States, the agricultural research program, which has the best documented record of production of economic benefits, is probably under the heaviest criticism at present? Has the system suddenly become flawed and unproductive? Has research quality declined? Have the agricultural sciences lost contact with the mother sciences?

I do not propose to answer these questions definitively in this paper. It will be useful to have them in mind, however, as we review the evidence on economic benefits. I will also attempt to offer a few comments about what we know about the quality of agricultural research by examining some data on scientific publications and information exchange.

I. Economic Benefits from Research: The Evidence

Most studies of economic benefits from research attempt to identify the contribution made by investment in an agricultural research program to future productivity gains in agricultural production. Research conducted in agricultural experiment stations directed toward post-harvesting technology (food processing, marketing, etc.) or household production activities (food preparation, clothing, etc.) has generally not been included in these studies. It will be useful to first explore the meaning of the term productivity before proceeding to an examination of the research studies.

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Table 1 summarizes average annual rates of change in total farm output, labor and land inputs, and labor, land, and total productivity. The reader will note that labor productivity growth in American agriculture has been extraordinarily high since 1925. Land productivity growth has been much lower although it was quite high since 1925. Land productivity growth has been much lower although it was quite high in the 1950-65 period. The real measure of efficiency gains in agriculture, however, is the total productivity growth measure. From 1950-65 this measure grew at an annual rate of 2.2 percent. This was somewhat higher than the comparable growth in other sectors of the U.S. economy. Total productivity growth declined to 1.8 percent in the 1965-79 period, but this growth rate was substantially higher than for the rest of the economy for this period.

Table 1: Average Annual Rates of Change (Percentage per Year) in Total Output, Inputs, and Productivity in U.S. Agricultural, 1870-1979

Item	1870-1900	1900-1925	1925-1950	1950-1965	1965-1979
Farm output	2.9	0.9	1.6	1.7	2.1
Total inputs	1.9	1.1	0.2	-0.4	0.3
Total productivity	1.0	-0.2	1.3	2.2	1.8
Labor inputs[a]	1.6	0.5	-1.7	-4.8	-3.8
Labor productivity	1.3	0.4	3.3	6.6	6.0
Land inputs[b]	3.1	0.8	0.1	-0.9	0.9
Land productivity	-0.2	0.0	1.4	2.6	1.2

Sources: Data from USDA, Changes in Farm Production and Efficiency (Washington, D.C.: 1979); and D. D. Durost and G. T. Barton, Changing Sources of Farm Output (Washington, D.C.: USDA Production Research Report No. 36, February 1960). Data are three-year averages centered on the year shown for 1925, 1950, and 1965.

a. Number of workers, 1879-1910; worker-hour basis, 1910-1971.

b. Cropland used for crops, including crop failure and cultivated summer fallow.

The results of a large number of studies of the contribution of research to this productivity growth have been assembled in Table 2. Almost all of these studies indicate high rates of return to investment in agricultural research--well above the 10 to 15 percent (above inflation) that private firms consider adequate to attract investment. It is hard to imagine many investments in either private- or public-sector activities that would produce more favorable rates of return.

The contributions of research to increased agricultural productivity have been studied primarily by two methods. The estimates listed under the "index number" heading in Table 2 were computed directly from the costs and benefits of research on, for example, hybrid corn. Benefits were estimated by using accounting methods to measure the increase in production attributed to hybrid corn. The contribution of research was usually measured as the residual after all other factors that contributed to increased production were accounted for. The calculated returns represent the average rate of return per dollar invested over the period studied with the benefits of past research assumed to continue indefinitely. Benefits are defined as the benefits retained in the form of higher incomes to producers or passed on to consumers in the form of lower food prices.

The estimates listed under the "regression analysis" heading are computed by a different method which permits estimation of the incremental return from increased investment rather than the average return from all investment. Further, this method can assign parts of the return to different sources, such as scientific research and extension advice. Because regression methods are used the significance of the estimated returns from research can be tested statistically. The dependent variable is the change in total productivity and benefit is defined as the value of the change in productivity. The independent variables include research variables which reflect the cost of research and the lag between investment and benefit. The objective of the regression procedure is to estimate the component of the change in productivity that can be attributed to research.

These studies report estimates of added product due to research investment. Several have estimated the time lag between research expenditures and the realization of economic benefits. These estimates generally show that a given research investment requires from 10 to 15 years before its full effect is realized. The average lag between investment and benefit is thus around five to six years for very applied research and seven to 10 years for more basic research.

The rate of return reported in the table is based on the calculated increase in product and the time lag. A typical estimate is that a $1 investment in time period t produces additional farm product rises over a period of 10 to 12 years to $7. We can then ask what rate of return is realized on an investment of $1 that yields an income stream beginning two years after investment and rising to an annual level of $7 by the 12th year and continuing at that level thereafter. In this case the internal rate of return on that investment is approximately 45 percent. As the table shows, many research programs yield benefits this large or larger.

A detailed study of agricultural productivity in the United States is summarized in Table 3. This study was of the regression type; changes in the productivity of American agriculture from 1868 to 1971 were related to the research performed by the state agricultural experiment stations and the U.S. Department of Agriculture. The effects of agricultural extension and the education of farmers were also taken into account.

Table 2: Summary Studies of Agricultural Research Productivity

Study	Country	Commodity	Time Period	Annual Internal Rate of Return (%)
Index Number:				
Griliches, 1958	USA	Hybrid corn	1940-1955	35-40
Griliches, 1958	USA	Hybrid sorghum	1940-1957	20
Peterson, 1967	USA	Poultry	1915-1960	21-25
Evenson, 1969	South Africa	Sugarcane	1945-1962	40
Barletta, 1970	Mexico	Wheat	1943-1963	90
Barletta, 1970	Mexico	Maize	1943-1963	35
Ayer, 1970	Brazil	Cotton	1924-1967	77+
Schmitz & Seckler, 1970	USA	Tomato harvester, with no compensation to displaced workers	1958-1969	37-46
		Tomato harvester, with compensation to displaced workers for 50% of earnings loss		16-28
Ayer and Schuh, 1972	Brazil	Cotton	1924-1967	77-110
Hines, 1972	Peru	Maize	1954-1967	35-40[a] 50-55[b]
Hayami and Akino, 1977	Japan	Rice	1915-1950	25-27
Hayami and Akino, 1977	Japan	Rice	1930-1961	73-75
Hertford, Ardila Rocha, and Trujillo, 1977	Colombia	Rice	1957-1972	60-82
		Soybeans	1960-1971	79-96
		Wheat	1953-1973	11-12
		Cotton	1953-1972	none
Pee, 1977	Malaysia	Rubber	1932-1973	24
Peterson and Fitzharris, 1977	USA	Aggregate	1937-1942	50
			1947-1952	51
			1957-1962	49
			1957-1972	34
Wennergren and Whitaker, 1977	Bolivia	Sheep	1966-1975	44
		Wheat	1966-1975	-48
Pray, 1978	Punjab (British India)	Agricultural research and extension	1906-1956	34-44
	Punjab (Pakistan)	Agricultural research and extension	1948-1963	23-37
Scobie & Posada, 1978	Bolivia	Rice	1957-1964	79-96

Table 2: Continued

Study	Country	Commodity	Time Period	Annual Internal Rate of Return (%)
Pray, 1980	Bangladesh	Wheat and rice	1961-1977	30-35
Regression Analysis:				
Tang, 1963	Japan	Aggregate	1880-1938	35
Griliches, 1964	USA	Aggregate	1949-1959	35-40
Latimer, 1964	USA	Aggregate	1949-1959	not significant
Peterson, 1967	USA	Poultry	1915-1960	21
Evenson, 1968	USA	Aggregate	1949-1959	47
Evenson, 1969	South Africa	Sugarcane	1945-1958	40
Barletta, 1970	Mexico	Crops	1943-1963	45-93
Duncan, 1972	Australia	Pasture Improvement	1948-1969	58-68
Evenson and Jha, 1973	India	Aggregate	1953-1971	40
Cline, 1975 (revised by Knutson and Tweeten, 1979)	USA	Aggregate	1939-1948	41-50[c]
		Research and extension	1949-1958	39-47[c]
			1959-1968	32-39[c]
			1969-1972	28-35[c]
Bredahl and Peterson, 1976	USA	Cash grains	1969	36[d]
		Poultry	1969	37[d]
		Dairy	1969	43[d]
		Livestock	1969	47[d]
Kahlon, Bal, Saxena, & Jha, 1977	India	Aggregate	1960-1961	63
Evenson & Flores, 1978	Asia - national	Rice	1950-1965	32-39
			1966-1975	73-78
	Asia - International	Rice	1966-1975	74-102
Flores, Evenson & Hayami, 1978	Tropics	Rice	1966-1975	46-71
	Philippines	Rice	1966-1975	75
Nagy & Furtan, 1978	Canada	Rapeseed	1960-1975	95-110
Davis, 1979	USA	Aggregate	1949-1975	66-100
			1964-1974	37
Evenson, 1979	USA	Aggregate	1868-1926	65
	USA	Technology oriented	1927-1950	95

Table 2: Continued

Study	Country	Commodity	Time Period	Annual Internal Rate of Return (%)
	USA	Science oriented	1927-1950	110
	USA	Science oriented	1948-1971	45
	Southern USA	Technology oriented	1948-1971	130
	Northern USA	Technology oriented	1949-1971	93
	Western USA	Technology oriented	1948-1971	95
	USA	Farm management research and agricultural extension	1948-1971	110

Source: Robert E. Evenson, Paul E. Waggoner, and Vernon W. Ruttan, "Economic Benefits from Research: An Example from Agriculture," Science, 205 (September 14, 1979), pp. 1101-7. Copyright 1979 by the American Association for the Advancement of Science.

a. Returns to maize research only.
b. Returns to maize research plus cultivation "package."
c. Lower estimate for 13-, and higher for 16-year time lag between beginning and end of output impact.
d. Lagged marginal product of 1969 research on output discounted for an estimated mean lag of 5 years for cash grains, 6 years for poultry and dairy, and 7 years for livestock.

Table 3: Estimated Impacts of Research and Extension Investments in U.S. Agriculture

Period and Subject	Annual Rate of Return (%)	Percentage of Productivity Change Realized in the State Undertaking the Research
1868-1926:		
All agricultural research	65	not estimated
1927-1950:		
Technology-oriented agricultural research	95	55
Science-oriented agricultural research	110	33
1948-1971:		
Technology-oriented agricultural research		
South	130	67
North	93	43
West	95	67
Science-oriented agricultural research	45	32
Farm management and agricultural extension	110	100

Source: Robert E. Evenson, Paul E. Waggoner, and Vernon W. Ruttan, "Economic Benefits from Research: An Example from Agriculture," Science, 205 (September 14, 1979), pp. 1101-7. Copyright 1979 by the American Association for the Advancement of Science. Note: The regression equation, standard errors of parameters (in parenthesis), coefficients of determination (adjusted for degree of freedom), and numbers of observations (N) are as follows:

1868-1926

(1) $P = 45.29 + \underset{(.162)}{.521}\ INV + \underset{(.171)}{.813}\ RES + \underset{(23.38)}{3.04}\ LANDQ$

$R^2 = .634; N = N = 40$ years

1927-1950

(2) $LN(P) = \underset{(.24)}{1.40}\ LN(INV) + \underset{(.037)}{.106}\ LN(TRES) + \underset{(.0000033)}{.0000053}\ LN(TRES)*(SRES)$

$R^2 = .503; N = 24$ years x 4 regions

1948-1971

(3) $LN(P) = \underset{(.0085)}{.0031}\ (LN(TRES.S) + \underset{(.0085)}{.0199}\ LN(TRES.N) + .0187\ LN\ (TRES\text{-}W)$

$+ \underset{(.0710)}{.2061}\ LN(TRES)*(SRES) + \underset{(.0426)}{.3540}\ LN(ED) - \underset{(.0097)}{.0394}\ LN\ (EXT)$

$- \underset{(.0021)}{.0116}\ LN(EXT)*ED + \underset{(.0230)}{.1821}\ LN(TRES)*EXT$

$R^2 = .569; N = 23$ years x 48 states

(4) $LN(P) = \underset{(.0090)}{.0299}\ LN(TRES\text{-}S) + \underset{(.0090)}{.0040}\ LN(TRES\text{-}N) + \underset{(.0090)}{.0113}\ LN(TRES\text{-}W)$

$+ \underset{(.0104)}{.5639}\ LN(TRES)*SRES + \underset{(.0369)}{.5855}\ LN(ED) - \underset{(.0102)}{.02539}\ LN(EXT)$

$- \underset{(.0021)}{.0196}\ LN(EXT*ED) + \underset{(.0044)}{.1369}\ LN(TRES)*EST + \underset{(.00017)}{.00148}\ LN(TRES)*SUB$

$R^2 = .595; N = 23$ years x 48 states.

Each equation also included region and time period dummy variables. The 1948-1971 equations also included a business-cycle variable and a cross-sectional scaling variable.

Variables: P: total productivity index; INV: index of invention; RES: stock of all agricultural research with time weights; LAND: land quality; TRES: stock of technology-oriented research with time and pervasiveness weights (S'W'N, for South, West, North); SRES: stock of science-oriented research; ED: schooling of farm operators; EXT: extension and farm management research stocks; LN is natural logarithm; *indicates variables multiplied.

During the period between 1868 and 1926, an estimated 65 percent annual rate of return was realized on this investment. From 1927 to 1950, the research was divided into two types. The first was called technology-oriented and was defined as research in which new technology was the primary objective. This included plant breeding, agronomy, animal production, engineering, and farm management. The second type was called science-oriented. Its primary objective was answering scientific questions related to the production of new technology. Science-oriented research included research in phytopathology, soil science, botany, zoology, genetics, and plant and animal physiology at the state experiment stations or the U.S. Department of Agriculture. The science-oriented research analyzed here is conducted in institutions in which it is closely associated with technology-oriented research. It is possible that the results might not apply, or would apply with a longer time lag, to science-oriented research isolated by organizational or disciplinary boundaries.

From 1927 to 1950, technology-oriented research yielded a rate of return of 95 percent. During the same 23 years, science-oriented research yielded a 110 percent rate of return, even more than technological research. The years 1927 to 1950 were a period of substantial biological invention, exemplified by hybrid corn, and improvements in the nutrition of plants and animals and in veterinary medicine. It was also a period of rapid mechanization. It is important to notice in the equations in Table 3 that science-oriented research does not have a signficant independent effect. The high payoff to science-oriented research is achieved only when it is directed toward increasing the productivity of technology-oriented research.

Research conducted in one state changes productivity in other states. This is referred to as "spillover." It has been estimated that, for 1927 to 1950, 55 percent of the change in productivity attributed to technology-oriented research from a typical state was realized within that state. The remaining 45 percent was realized in other states with similar soils and climate. The spillover from science-oriented research was considerably greater. The observations of 1948 to 1971 for individual states allowed still more detailed analysis. Technological research continued to yield returns of over 90 percent. The payoff to research was especially high in the South where research had lagged in earlier periods. Science-oriented research remained profitable as it interacted with technological research, but it was less profitable than during 1927 to 1950.

Evidence concerning the effects of the education of farmers and the availability of extension advice on productivity can also be obtained from the equation used to estimate the results presented in Table 3. The schooling of farm operators had a direct positive effect. The effect of extension education and farm management advice is more complex. It was particularly beneficial in those states with both considerable technological research and farmers with little schooling. The effect of these interactions, combined with the direct effects of extension, was positive.

The effect on productivity of decentralization of scientists to substations was also captured by the regression equations in Table 3. There has been considerable debate on how a shift in the distribution of scientists between the central state stations and substations would affect the productivity of technological research. In the regression equation, the fraction in the substation is multiplied by technological research. The interaction was positive and significant, indicating the decentralization has had a positive effect on the productivity of state research systems.

These studies can be summarized very succinctly. A large number of studies based on alternative methodologies and examining different types of research programs show that agricultural research has produced added productivity or output per unit of input of sufficient magnitude to yield extraordinarily high rates of return to investment.

II. Research Quality Issues

Much of the recent criticism of agricultural research has centered on the issue of research "quality." The term quality is not really defined and the judgment of research quality is generally a peer review judgment. In a recent paper a colleague, Brian Wright, and I attempted to develop more systematic quality criteria for applied sciences such as the agricultural sciences. We argued that quality judgments should properly differ according to the degree of application or inventiveness of the research. Research devoted to the direct discovery of technology can be evaluated according to its success in the discovery of usable technology. High quality research is research with a high ratio of valuable technology discovery to resources devoted to the research.

As we move "upstream" along the spectrum from research directed toward technology discovery to research directed toward the discovery of more fundamental knowledge the criteria for research quality must change. It is not possible to place value directly on knowledge discovered (actually it is often difficult to value technology until after it has been diffused among farmers as well). The basic or general sciences have generally substituted a peer-review system and a related scientific publications system for the direct evaluation of product technology possible for the most applied research. The product of this research is the scientific paper which serves as a vehicle for "disclosing" as well as codifying knowledge. Journals have peer review processes which implicitly place quality judgments on papers. Research project support is often subjected to a similar peer review process as is academic promotion.

The agricultural sciences are appropriately seen as intermediate or "daughter" sciences. They retain much of the character of the general sciences but have a clear orientation to the direct discovery of useful technolgy. A successful intermediate or daughter science has three characteristics:

a. A mechanism for clientele demand articulation.

b. Direct and indirect technology weights in research quality evaluation procedures.

c. Strong mother-daughter bonds with upstream mother sciences.

The demand articulation between farmer interest group clientele and the agricultural sciences is particularly important. This articulation impinges on the organization of the agricultural sciences in important ways. It effectively inhibits project proposal peer review--especially upstream peer review. The clientele must have some say in the types of projects to be funded. If dairy farming interests are strong they will see to it that funding is available for research projects oriented to problems perceived by dairy farmers. These may differ from the problems perceived by dairy scientists. This creates tension within the system but on the whole it is healthy tension even though it may result in the funding of low quality research as perceived by agricultural scientists. Such research will almost certainly be perceived to be low quality by upstream scientists in the mother sciences.

Thus the effective daughter science is pressed by clientele articulation toward placing larger weights on the expected value of technology produced and smaller weight on scientific criteria than a peer review process. It not only does this for projects directed primarily toward technology discovery but also for projects directed toward knowledge discovery as well.

This means that it must have a means for articulating the problems of the technology discoveror upstream to the knowledge discoveror. It does this in several ways. Scientific papers can communicate and disclose and thus articulate. Project funding criteria can also facilitate this process. As a practical matter, however, effective daughter sciences have had to institutionalize this process to achieve articulation. They have found it necessary to bring a fairly broad range of the upstream-downstream spectrum of research specialties under one institutional roof so to speak.

There are three major institutional models in the agricultural sciences. One is the commodity institute. The best examples of this model are the International Agricultural Research Centers. These centers attempt to build interdisciplinary teams of scientists with a directive to improve the productivity of a particular commodity. The team includes very applied as well as more basic scientists. The second model is the experiment station model. Examples are most USDA stations and many government supported research centers in other countries. These stations are usually multi-commodity research stations and have a directive to improve productivity of all commodities (or at least most commodities) in a particular region. The third model is the United States State Land-Grant Experiment Station where teaching and extension functions are integrated with research in a multi-commodity region based station (usually with branch stations).

Which system works best? The studies of economic benefits to research cannot really answer that question definitively. They do show that the basic or science-oriented research supported within these institutional forms is highly productive. By inference we can probably conclude that such science-oriented research conducted in one of these institutional forms would be more productive than the same research conducted in alternative settings. Of the three institutional forms, the interdisciplinary commodity institute is least conducive and the land-grant model most conducive to a high science-oriented component in agricultural research. The commodity institute, on the other hand, can direct and concentrate research programs on a single set of problems more effectively. Each model has its advantages. The long-term experience in the United States' system suggests that the land-grant model works well when effective political means are available to region-based clientele interest groups. It may not work well when such means are lacking. The commodity center and the research institute models are more compatible with "top-down" bureaucracy organizations with a high degree of direction and planning control from a central bureaucracy. The commodity center model has the virtue in this context, that it is less likely to grow into a large bureaucracy than the research institute model.

High quality research can be and is conducted in all three models. The scientific paper and the efficient scientific communication of findings are important parts of the research process and of its quality. Wright and Evenson[4] undertook a study of research quality in post-harvest technology research (mainly food technology) conducted by the USDA and state experiment stations. We judged research quality by several criteria. We looked at publications and at patented inventions produced by research programs and compared these indicators of quality at different periods of time to reference groups. We also looked at citation patterns between scientific papers and patents. We concluded that citations are very important indicators of quality both in patent documents and in scientific literature.

Many public sector research projects are expected to influence downstream research and inventor's processes. One measure of this influence is upstream citation. Thus one wants to ask whether there is evidence of links between public sector research and downstream public and private invention in journal and patent citation patterns. Our study of USDA patenting showed that a majority of USDA patents were subsequently cited, indicating that there is significant interaction between applied public research and technology-producing invention in the private sector.

III. Research Support Issues

As noted earlier, agricultural research programs in the United States are currently being heavily criticized in spite of the evidence that research has produced high levels of benefits, particularly to consumers. This criticism centers on duplication of research, on fragmentation of research in small centers, particularly in federally funded research, and on general

research quality issues. The previous section discussed some of the factors centering on research quality and its measurement. We are not really in a good position to form strong judgments about quality. In fact we do not even have a clear understanding of the appropriate quality criteria.

United States agricultural research is certainly open to criticism on a broad range of grounds. Any public sector activity should be carefully scrutinized and asked to defend its programs. I suspect that we are approaching something of a watershed in agricultural research spending and conduct in the United States partly because of the drift in research programming in the past 15 years and partly because the research support base has been shifting. We may be seeing a build-up of pressures to force agricultural research programming to seek to build stronger mother-daughter science bonds to the mother sciences. This has happened several times before in the history of agricultural research. As I noted agricultural research organizations are always in a state of tension between the applied "practical" scientists and the more basic scientists. The balance of power shifts when problems become evident; when applied research is frustrated by the limitations of the scientific foundation, pressure builds up to move toward science. The recent development in genetics and other biological sciences provides signals to the daughter sciences that new opportunities for the applied sciences exist. The agricultural sciences probably have been slow to exploit these opportunities.

The argument is also being made that the federal component of the research system has been growing steadily weaker and has acquired a growing "pork-barrel" status over the past 15 to 20 years. Research and agricultural growth are not high on the USDA agenda these days. Indeed, we might expect a significant and growing part of the bureaucracy to be antagonistic toward production research as we enter a period of excess supply and associated farm income problems. Some see these factors as causing a decline in national leadership in agricultural research, although I doubt that the matter has been seriously examined. Whether leadership and research quality in the USDA have suffered declines seems to me to be somewhat debatable. It is clear, however, that the federal support base for research has not grown in pace with the value of agricultural products and that many state experiment stations receive relatively small parts of their budgets from federal funds.

The State Agricultural Experiment Stations have been receiving a growing portion of their funding from state funds. This support base, however, has been altered substantially in recent years. The reapportionment of state legislatures in the early 1960's caused a general reduction in the political power of farmers and of the rural population. A recent study by Rose-Ackerman and Evenson[5] concluded not only that a reduction in the support base for agricultural research and extension had occurred but also that the base had shifted from a farm income base to a rural population base. Since rural poulation has been growing at a lower rate than farm income this has resulted in a further erosion of the support base at the state level.

Another factor influencing public research support and, to a degree, public research conduct is the growth in the agriculturally related research activities of private industrial firms. Private firms in the agricultural machinery and chemical industries are becoming more important in the research picture because they are providing an increasing share of the resources used to produce agricultural products. Recent changes in plant variety protection laws are also stimulating more private sector activity in plant breeding. As these changes take place, it is important that the public sector research system be responsive to them and design its programs to compliment private sector activity. When the public research institution fails to respond and appears to be duplicating private sector research, it will very likely lose support.

The information systems in the agricultural sciences will probably take on a more important role as agricultural research is pressured into developing stronger mother-daughter bonds and into developing more effective relationships with the private sector. It would appear that they are moderately well equipped to assist the strengthening of mother-daughter bonds. The private-public bonds are another matter. Communication between these sectors is probably less than ideal. The improvement of these information flows will be important to the future development and vitality of the public sector agricultural research programs in the United States.

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MEETING U.S. AGRICULTURE'S NEEDS FOR SCIENTIFIC SPECIFICITY AND COMPREHENSIVENESS: ROLE OF STATE AGRICULTURAL EXPERIMENT STATIONS AND LAND-GRANT UNIVERSITIES

by

KEITH A. HUSTON

Our Symposium deals with 20th century agricultural science. During this century, publicly supported agricultural science has been a predominant feature of agricultural science. The major organizational components of publicly supported agricultural science and information, however, and their funding mechanisms were established not in the 20th century but in the 19th century--in a day when transportation, communications, agriculture, and society itself were vastly different from what they are now. Yet those components and mechanisms have persisted. In other sciences, the situation has been quite different.

Visible and massive public support there is a relatively recent feature--a post World War II phenomenon. That support has been through funding mechanisms in support of organizational components quite different from those of the agricultural science system. Only recently has there been much general interest among nonagricultural scientists in the comparative anatomy of agricultural and other sciences. What interest there is usually focuses on the nonconformity of the older more thoroughly tested and proven agricultural system with the newer system in other sciences. And nonconformity is taken as inferiority with no real effort to evaluate the differences.

The general organizational and funding structure of agricultural sciences is peculiarly suited to the broad needs of agriculture. That general structure permits sizeable diversity in approaches and accommodates within resource limitations evolutionary modifications in scientific subdisciplines.

The public agricultural science and information system is complex. Evenson, Ruttan, and Waggoner[1] have described it as a decentralized (both administratively and geographically) but articulated system. The system has many different contributing units. Some are federally directed; some, state directed. Some have as their principal responsibility agricultural, forest, and rural home and community affairs. Others touch on these affairs only coincidentally. Some are linked and interdependent; some, quite separate.

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Among those directly responsible for agricultural, forest, and rural home and community affairs, the state-directed units collectively encompass the major share of the nation's human, fiscal, and other resource investments (Figure 1). Each of 50 states, six territories, and the District of Columbia has its own units characteristically, but not entirely, a part of a state-supported university. In most states, all these units are administratively concentrated at a single state university (usually a single location), the state's "land-grant" university, usually a Ph.D. granting institution.

Typically, separate units functioning to generate, store, or transmit agricultural information include: (1) a state-wide research unit, the State Agricultural Experiment Station (Figure 2); (2) a state-wide, off-campus educational unit, the State Cooperative Extension Service; (3) one or more on-campus educational units, usually a college of agriculture and sometimes including colleges of forestry, home economics, veterinary medicine, and biological sciences; and (4) a library. Only the first two, the experiment station and the extension service, are administered by a director responsible not only to university officials but also to federal authorities of the USDA (Figure 3).

In many states, the agricultural units are administratively and functionally separate but are administratively coordinated through a single office of a Dean or Vice President. In other states, the units are administratively and functionally combined.

College Faculties: The Contrast Between Agriculture and Other Sciences

In colleges, the typical faculty member is employed for a nine-month academic year. In Ph.D. granting institutions, promotion and tenure are influenced not only by teaching skills but also and heavily by research or scholarly output. In fact, most Ph.D. granting institutions provide faculty lighter instructional responsibilities than do non-Ph.D. institutions so as to enable faculty to undertake research or scholarly activities in support of graduate programs. This "dedicated" research time likely ranges from 10 to 20 percent of the nine-month academic year.

Commencing in the 1950's, federal granting programs made grant-seeking a way of life for university science faculty outside agriculture. Those grants provided summer employment for the faculty, allowed them to employ part-time graduate research assistants during the academic and calendar year, and provided money for research investigations. Few grants, however, were for agricultural topics.

Figure 1

NATIONAL PUBLIC RESEARCH SYSTEM

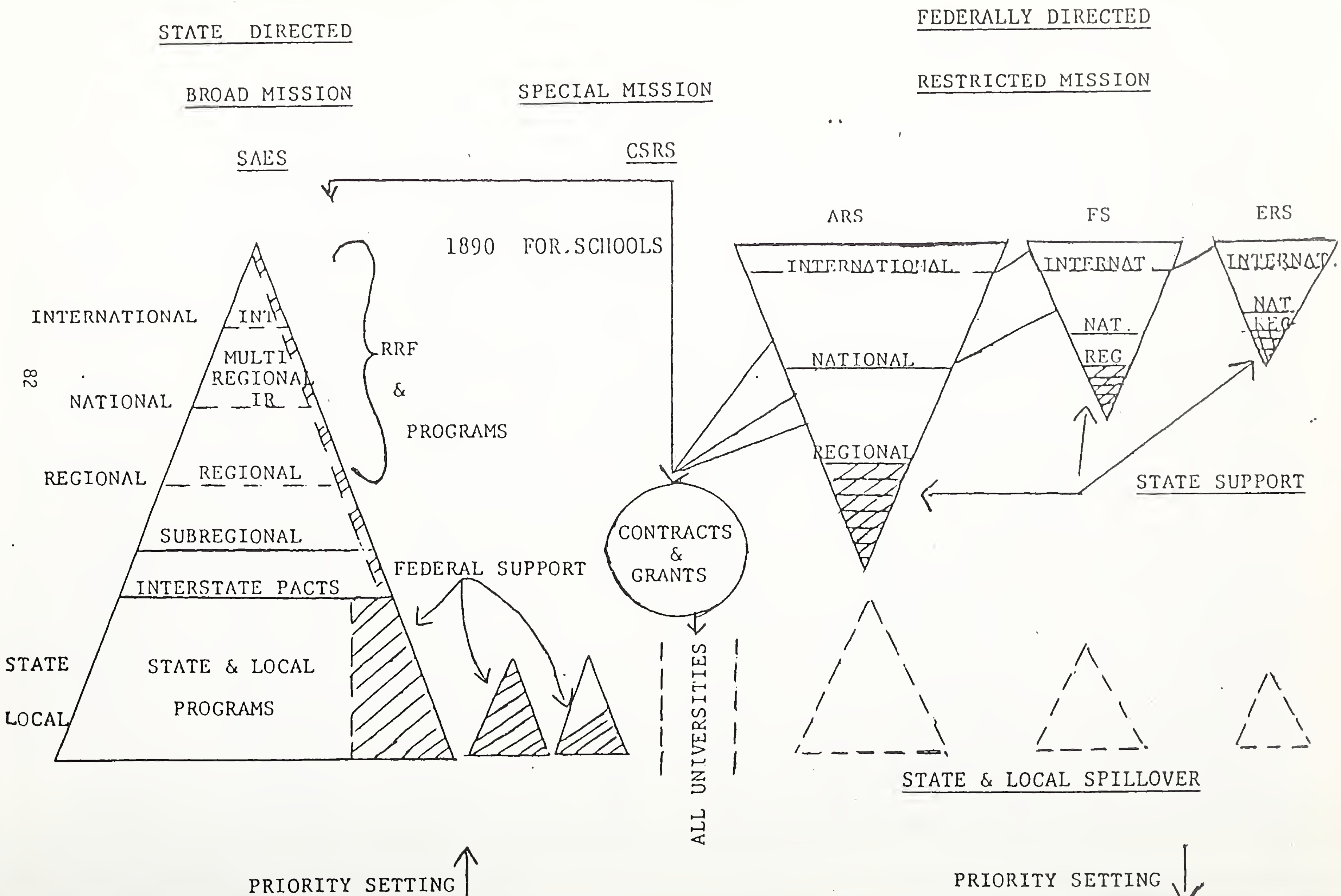


Figure 2

State Agricultural Experiment Station System

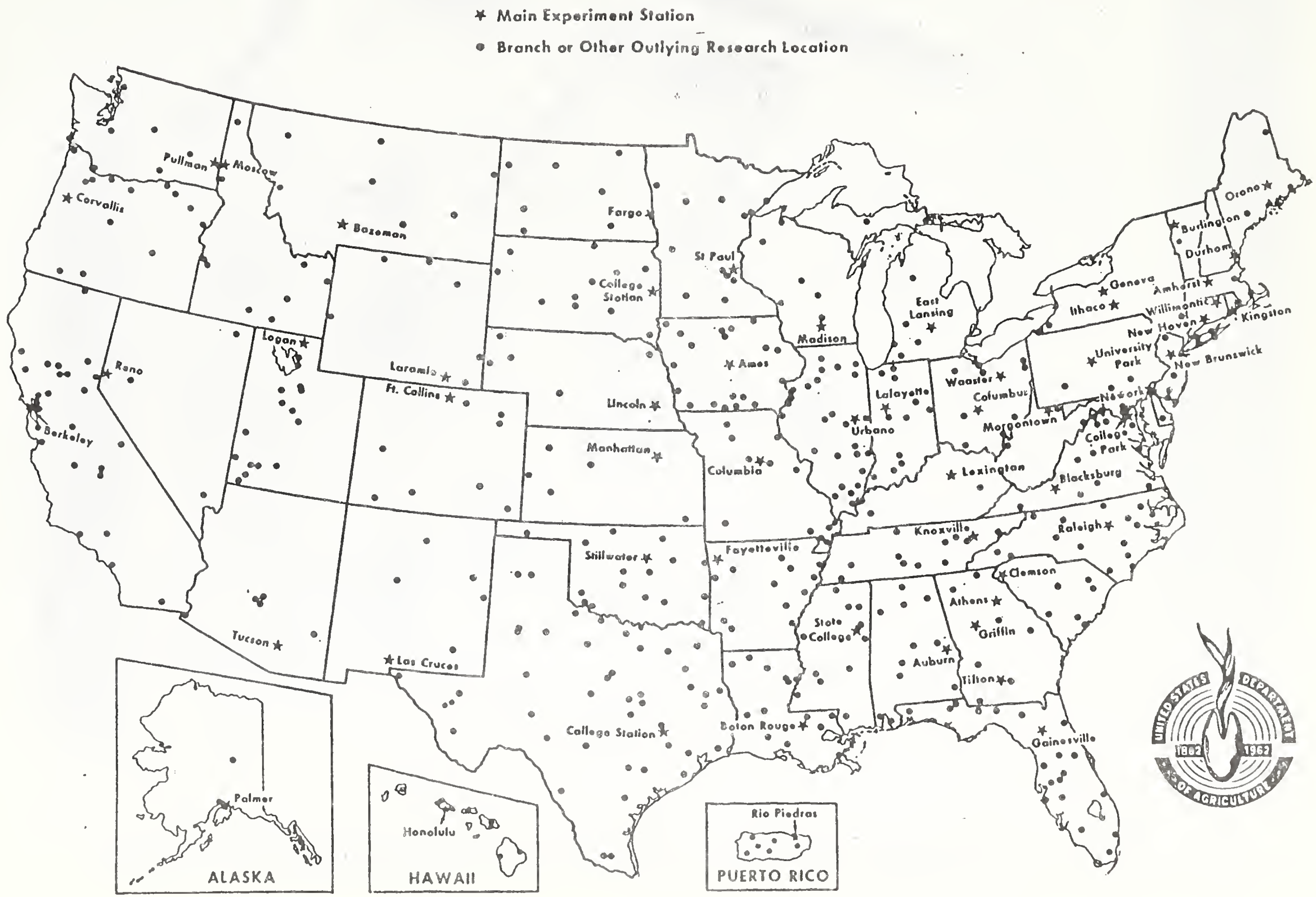
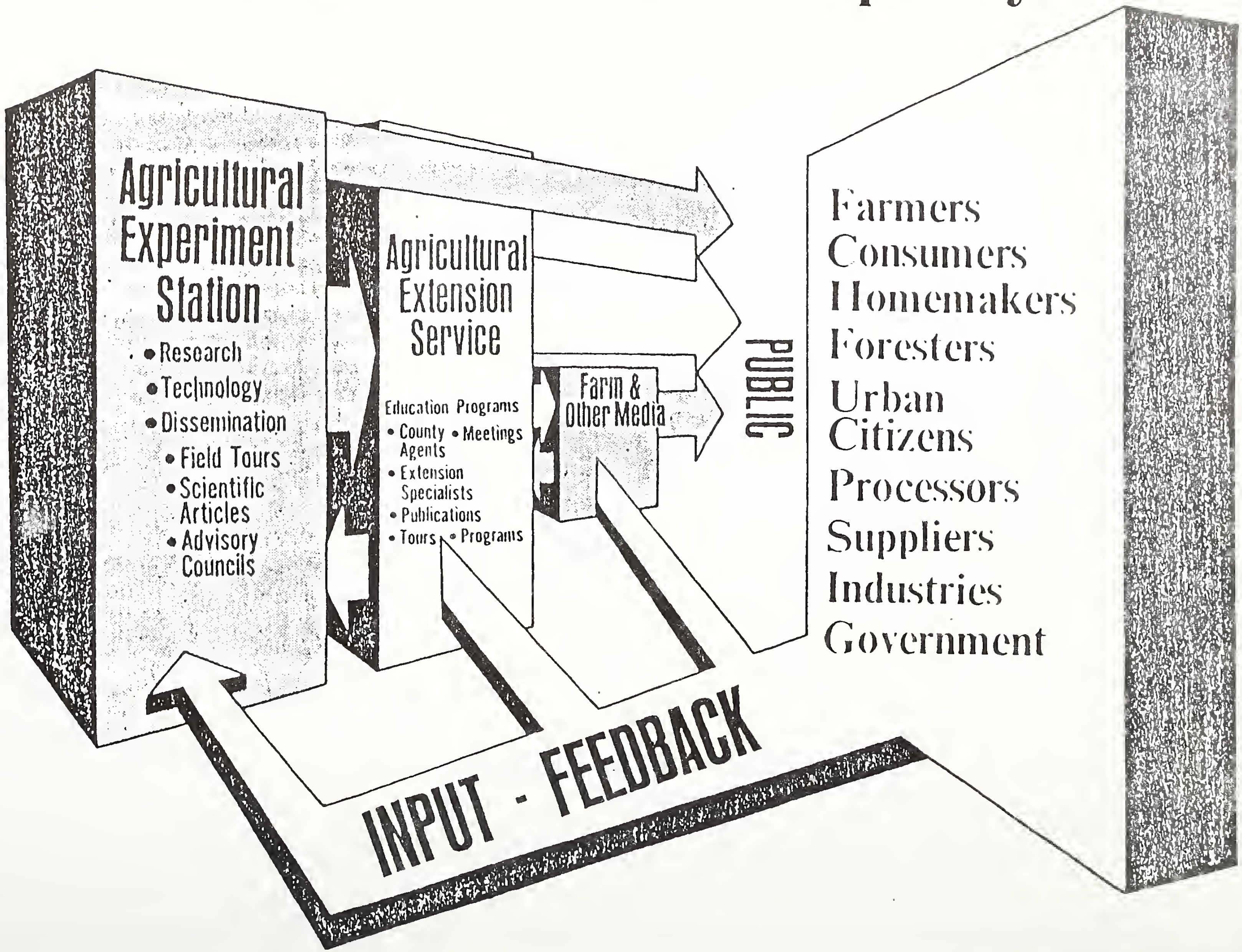


Figure 3

Information Transfer: An open system



The situation was different in agriculture. In agriculture, teaching faculty resources of Ph.D. granting institutions had been exploited on a permanent basis more than 50 years earlier. Early in their development, stations absorbed the "underemployed" research talents available in agricultural colleges. They joined with the Colleges of Agriculture in hiring and sharing faculty members on an 11-month basis rather than a nine-month basis appropriate to the teaching function. In this way, they could address the state's need for specific research on diverse topics. Thus, when federal granting programs commenced in the 1950's outside agriculture, the stations already were utilizing on a permanent basis the same types of "underutilized" faculty resources to be utilized by those federal granting agencies on a more irregular basis.

Unlike other sciences, that "underutilized" resource in agriculture is not very large, a fact that many persons outside agriculture do not realize. The instructional faculty in agricultural sciences in Ph.D. granting institutions nationally numbers roughly about 3,000 to 3,400 FTE. Utilization of both their "summer time" and their dedicated faculty research time contributes at most between 800 to 950 or so of the 6,700 FTE scientists employed nationally in the state agricultural experiment station. In some very important agricultural sciences (entomology, plant pathology) in some agricultural colleges, there often are only two or three teaching faculty--a hopelessly inadequate base for grant funding or as a science resource for the state's agriculture. An additional 1,000 or so university scientists teaching general sciences related to agricultural sciences are employed by stations on a similar basis. They constitute about 270 of the total 6,700 station scientist-years.

Thus, the stations can count on university instructional programs to provide base support for about 17-18 percent of their permanent station scientists. The remaining 5,400 to 5,600 scientists, at least 82 percent of the station's total, are the direct concerns of the stations alone. Put in another way, "hard money" positions in agriculture come from experiment station resources whereas those in other sciences come from instructional resources of the colleges.

Balancing State Research Needs: Diversity Versus Specificity

Agriculture and forestry usually are enormous, complex, land-based industries dispersed across most of each state's land. Their products are biological and thus perishable. Most primary products are produced out-of-doors where all the enormously variable and highly localized circumstances of nature and her unpredictable vagaries have an impact. Production also is influenced by localized economic, social, and political circumstances relating to services, transportation, credit, regulations, and the like. Once the products leave the farms and

forests, their transport, assembly, preservation, processing, marketing, and distribution involve another group of biological, economic, social, and political factors, some local, some regional, and some national.

The state agricultural experiment stations are responsible for providing research that is specific, balanced, and yet comprehensive with respect to important commodities produced anywhere in each state and for any subsequent intrastate activities (e.g., processing, food safety, human nutrition) involving those commodities as they leave the farm or forest. Responsibility extends also to commodities entering from other states. State agricultural experiment stations also are responsible for research that arises from needs of regional and national food-related activities located in each state (e.g., food processors in Minnesota; grain elevators in Kansas).

The state agricultural experiment stations are also responsible for research to protect and conserve each state's natural resources, environment, economic wealth of its individuals engaged in the food and forest industries (principally farmers), and rural home and community needs. This responsibility is a natural one. The stations and their scientists are "on the scene" where they can see and hear the local needs and respond promptly. They also are located with and closely tied to the cooperative extension service, the state technology transfer system.

The state agricultural experiment station programs are comprehensive and balanced but they are not necessarily sufficient nor complete from either a state, regional, or national perspective. The incompleteness or insufficiency of state agricultural experiment station programs stems from the complexity of each state's agriculture and from the large number of natural agroclimatic production areas in each state. Most states produce from 15 to 50 or more economically important commodities, though some have as few as nine or 10 and some, as many as 200 or more. Most states have from four to 15 or more natural agroclimatic production areas. The research issues that arise from this complex of commodities and locations and from other research responsibilities require an enormous diversity and number of research scientists and supporting resources in each state agricultural experiment station. No station has sufficient resources to address them completely.

Addressing State Research Needs: Diversity Versus Specificity in the Sciences

The kinds of scientists required for agricultural research are determined by the kinds of commodities produced and processed in the state and other research responsibilities of the state agricultural experiment stations. Usually at least 10 to 15 different agricultural

sciences are involved. Within each of those sciences, there are five to eight major specialties and numerous sub-specialities. Thus, a balanced and comprehensive research program might require the permanent services of 50 to 100 different kinds of specialty scientists. A complete program might require an additional 30 to 50 kinds of specialty scientists, some from nonagricultural sciences and some from agricultural science sub-specialties.

The effort needed in each science specialty must also be considered. As noted earlier, in most states the number of different commodities typically ranges from 15 to 20 and the number of agroclimatic areas from four to 15. Thus, if just one of each kind of scientific specialist were to be provided for each major commodity with some attention to area agroclimatic needs, a state agricultural experiment station might require an array of commodity-scientific discipline specialists ranging from 200 to 2,000 or more. No state makes that sort of commitment to agricultural research (Figure 4).

All commodities are not of equal importance in a state nor are other areas of research responsibility. Thus, varying quantities of effort are expended in each commodity-scientific discipline specialty. That would be difficult to arrange were it not that station scientists can be employed on a part-time basis or can effectively engage in research on several commodities. Fortunately, both options are open to state agricultural experiment stations. Part-time scientists can be shared with colleges of agriculture and the cooperative extension service. In some science specialties, one individual can handle effectively several commodities.

Each research scientist requires supporting resources. Part-time research scientists require and can use disproportionately larger amounts of resources than full-time research scientists. Although part-time employment of scientists permits state agricultural experiment stations to allocate those resources more efficiently, it is not so sparing in allocating support resources. Most state agricultural experiment stations find it difficult to divide resources between scientists and their need for support. The need by state agricultural experiment stations for science specialties is so diverse and great that all resources easily could be invested in scientists. Most stations resolve the issue by hiring as many scientists as possible while providing them less than optimal support resources. That explains why most agricultural scientists seek grant, contract, and other types of supplemental resources. That also explains the importance attached to federal formula support. Without that continuing stable support, stations would find it immensely difficult to maintain balanced and comprehensive programs. If the states were unable to provide balanced and comprehensive programs, the responsibility would fall directly on the federal agencies which would require additional resources. Because the federal agencies have less exposure to agroclimatic and other localized needs in states, it is unlikely that they could be as effective in utilizing those funds as the state agricultural experiment stations.

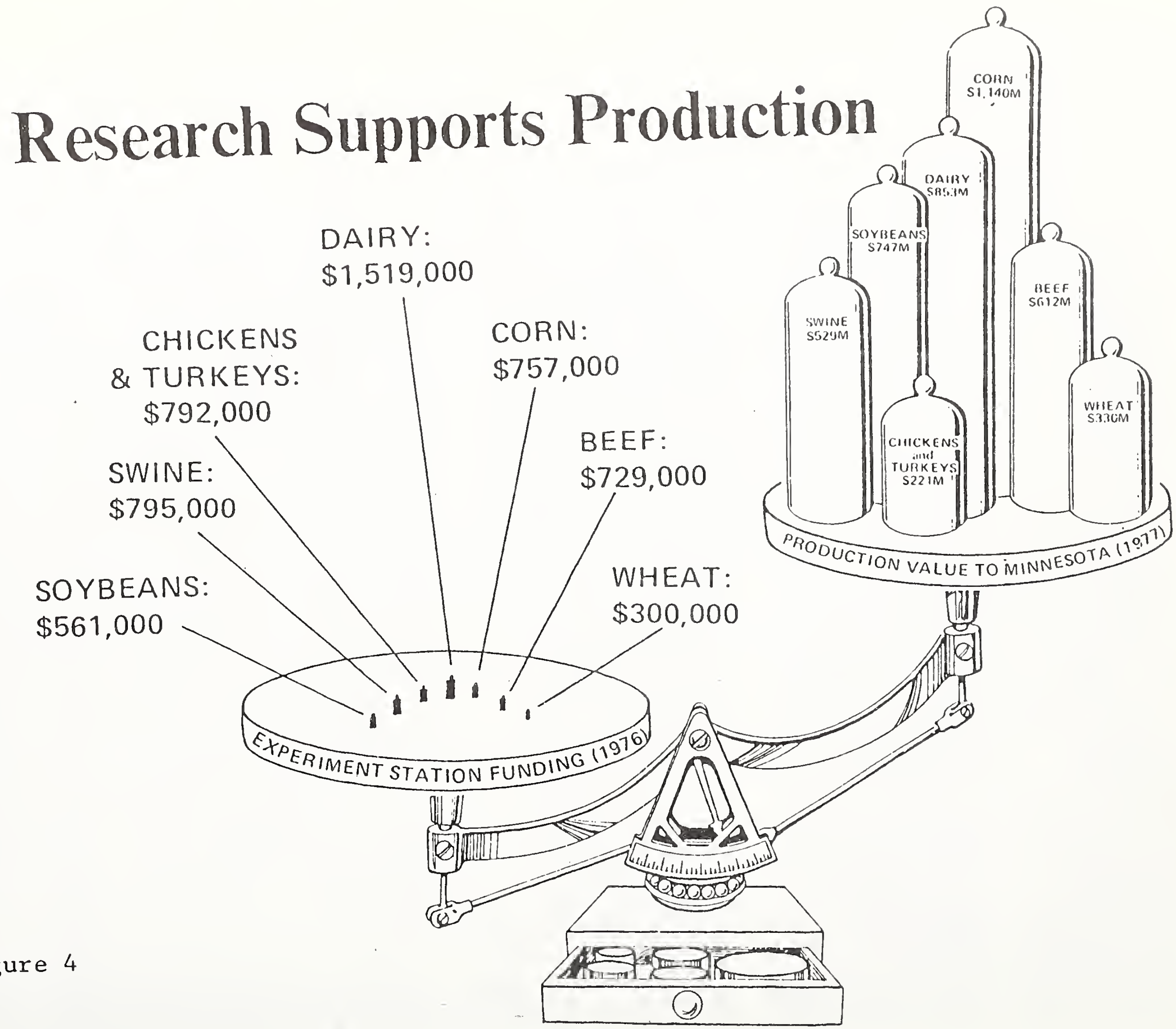

Research Supports Production
DAIRY:
$1,519,000
CHICKENS
& TURKEYS:
$792,000
CORN:
$757,000
BEEF:
$729,000
SWINE:
$795,000
SOYBEANS:
$561,000
WHEAT:
$300,000
EXPERIMENT STATION FUNDING (1976)
CORN
$1,140M
DAIRY
$853M
SOYBEANS
$747M
SWINE
$529M
BEEF
$612M
CHICKENS
and
TURKEYS
$221M
WHEAT
$330M
PRODUCTION VALUE TO MINNESOTA (1977)

Figure 4

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THE CENTENNIAL OF THE EXPERIMENTAL FARM SERVICES, 1886 - 1986

by

J. W. MORRISON

INTRODUCTION

An Act Respecting Experimental Farm Stations (2nd June, 1886):

> WHEREAS it is expedient to establish experimental farm stations as hereinafter provided, for the promotion of agriculture, by the dissemination of useful and practical information respecting matters connected therewith: Therefore Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:--
>
> This Act may be cited as 'The Experimental Farm Station Act.' The Governor in Council may establish, first, a farm station for the Provinces of Ontario and Quebec jointly; secondly, one for the provinces of Nova Scotia, New Brunswick and Prince Edward Island jointly; thirdly, one for the Province of Manitoba; fourthly, one for the Northwest Territories of Canada, and fifthly, one for the Province of British Columbia; and the farm station for the Provinces of Ontario and Quebec jointly shall be the principal or central station.[1]

So began the Experimental Farm Services in Canada in 1886. Behind the passage of the Act is the story of politicians, of farmers' associations seeking help from their elected members of parliament, of established settlers living in Eastern Canada, of new pioneers breaking the western prairie sod, and of knowledge-seeking citizens, sometimes self-educated, who were practising the science of agriculture or biology before many fundamentals were known and very few reference books were available.

Editorials and press articles on parliamentary matters were common then as today. As a theme for these articles you can imagine that the major questions would have been: "What good will these farms be to the agricultural community?" To answer what was expected, I shall refer to other sections of the Act. For the Centennial, I propose to answer the question: What good have these farms been to the agricultural community?"

The Need for Experimental Farms

While progressive community spokesmen and leading farmers were experimenting with different varieties and crop kinds, with ways and means to reduce losses from insects and diseases, and with modifications to farm equipment and changes in farm practices, little verified information was available to the average settler or land-owner in the early to mid-1800's. The need seen by the farming community and translated into demands to the political representatives was for some government assistance to provide continuity and a scientific approach to the solving of common problems. It was argued that any such government organization could bring to bear on Canadian conditions

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as well the experience from other countries, such as the use of chemical fertilizers being advocated by biologists and chemists from Rothamsted in England.

A second need that was coming sharply into focus around 1880 was knowledge and technology that would permit survival of settlers in the Northwest Territories. The few settlers clustered around Winnipeg and trading posts in the West had not been able to grow winter wheat because of the cold winters; spring grown cereals frequently were caught by an early fall frost. The years of 1883 and 1884 were particularly bad.

Those same two years saw the building of Canada's transcontinental railway across the prairies. While the last spike to complete the ribbon of steel was not driven home until 1885 in a remote mountainous section of British Columbia, a flourishing business of moving settlers to Western Canada was underway as soon as the prairie sector was finished and a link with Eastern Canada completed. Few of these inexperienced settlers had the skills, knowledge, or equipment to make farming profitable and the government that was actively promoting settlement had an obligation to provide technical assistance.

The Formal Beginning

In January of 1884, a Select Committee of the House of Commons, headed by G. A. Gigault, Member of Parliament for Rouville, Quebec, and known as the Gigault Committee, was appointed to investigate the need for agricultural improvement.[2] After holding meetings, sending out questionnaires, and calling witnesses, this Committee presented a valuable report suggesting the establishment of a Bureau of Agriculture and an Experimental Farm in connection therewith. It was recorded that the Minister of Agriculture placed $20,000 in estimates for 1884 for work in connection with an experimental farm.

On November 2, 1885, William Saunders, a self-educated druggist, botanist, plant breeder, horticulturist, entomologist, chemist, musician, and community leader was appointed to investigate the function of experimental farms especially in the United States. His masterly report, dated February 20, 1886, recorded fully what was being done in the United States, also more cursorily, what had been done elsewhere throughout the world. It made note of forestry work and botanic gardens established in various countries and recommended that work be undertaken in Canada. The report was presented to the House of Commons by the Honorable Mr. Carling, Minister of Agriculture, on April 15, 1886 and a bill bearing the title, "An Act Respecting Experimental Farm Stations" passed its third reading on May 12. On June 2, it received Royal Assent.

Land was purchased for the Central Experimental Farm near Ottawa in 1886; 20 acres were ploughed, stones and tree stumps were removed, and a small building was erected in which to test the vitality (germination) of seeds. As a matter of interest, 187 samples of cereals and grasses from local farmers were tested that winter.

Sites for the other experimental farms were chosen, land was purchased, and, soon, the network of five stations was completed. Every year, the Director was required to report to Parliament on the conduct of research. These reports would chronicle his travels to select sites, his choice of superintendents, and the quickness in getting about the country now that the new railway was operating.[3]

ORGANIZATION FOR RESEARCH

Stations

The Act specified that five stations be established. This was done quickly at Nappan, Nova Scotia; Ottawa, Ontario; Brandon, Manitoba; Indian Head, Northwest Territories, and Agassiz, British Columbia. Ottawa was the headquarters for operations. (Fig. 1)

As years passed, the usefulness of the initial farms soon created demands in all provinces and, after the turn of the century, farms were established at Lethbridge, Lacombe, Kentville, etc. until today, we have some 47 units stretching from St. John's in Newfoundland to Saanichton on Vancouver Island. Not all the stations that were opened exist today. Notably, Mile 1019 on the Alaskan Highway in the Yukon and Fort Simpson in the present Northwest Territories were open for only some 20 years. At the same time, we have enlarged operations at the Central Farm and have there seven research units. For the record, the staff numbered 1,400 in 1936 and presently is 3,640.

The first management organization under William Saunders was a series of divisions, established at Ottawa, usually under the leadership of one specialist. The Botany and Entomology Division was the first specialized division formed. Others were cereals, horticulture, agriculture (animals), chemistry (mostly soils), and forage. As responsibilities increased, so did the staff but the Director retained line authority over all superintendents at Branch farms. Correspondence had increased at an alarming rate. In 1889, 6,864 letters were received and the following year, 17,539, of which 11,739 were addressed to William Saunders, the Director.[4] With no copying machines available, the clerks must have been kept busy.

In 1910, the chiefs of the various divisions in Ottawa became responsible for activities in their specialty throughout the entire farm system. Entomology became a separate branch in 1914. In 1937, research farms and stations were split into two groups: Experimental Farm Service and Science Service. Entomology and botany (pathology) were large forces in Science Service. The war years saw some retrenchment but a rapid increase occurred in 1946-50 when veterans were taken on strength and supported for educational leave. The two services remained apart until 1959 when both were reunited as the Research Branch. Since then the authority for the Research Branch has been regionalized and while Branch Headquarters remains in Ottawa, the regions of Atlantic, Quebec, Ontario, and Western Region have been formed.

Figure 1 - Map of Canada showing the location of the first five research stations established by the Experimental Farms Act of 1886.

Directors

The first Director of the Experimental Farm Services was Professor William Saunders. When he retired in 1911, J. H. Grisdale directed activities until he was elevated to become Deputy Minister of the Department of Agriculture in 1919. He was succeeded by Dr. E. S. Archibald, another man of amazing stamina and ability. He was feared and respected by all superintendents and molded the newly-formed stations into an effective national network. He retired in 1949.

An entomologist, Dr. Fletcher, who worked in the Parliamentary Library was appointed Honorary Entomologist in 1884 and then moved into a salaried position in 1887. Others of the Old Guard included Dr. F. T. Shutt as chemist, W. T. Macoun as horticulturist, J. W. Robertson as agriculturist, and A. G. Gilbert in poultry. In 1903, William appointed his son, Charles, a musician, poet, and chemist as Dominion cerealist. More shall be heard of him.

Program of Work Proposed

Let me now return to the Act for the specific instructions for research required in 1886. For brevity and convenience, I have shortened some items and rearranged them.

Animals: 1) Conduct researches and verify experiments designed to test the relative value, for all purposes, of different breeds of stock, and their adaptability to the varying climatic or other conditions which prevail in the several Provinces and in the Northwest Territories;

2) Examine into the composition and digestibility of feeds for domestic animals;

3) Investigate the diseases to which domestic animals are subject.

Crops: 1) Test the merits, hardiness, and adaptability of new or untried varieties of wheat or other cereals, and of field crops, grasses, and forage-plants, fruits, vegetables, plants and trees, and disseminate among persons engaged in farming, gardening or fruit growing, upon such conditions as are prescribed by the Minister, samples of surplus of such products as are considered to be specially worthy of introduction.

2) Examine into the diseases to which cultivated plants and trees are subject, and also into the ravages of destructive insects, and ascertain and test the most useful preventives and remedies to be used in each case;

3) Ascertain the vitality and purity of agricultural seeds.

Soils: Analyze fertilizers, whether natural or artificial, and conduct experiments with such fertilizers, in order to test their comparative value as applied to crops of different kinds.

Special: 1) Examine into the economic questions involved in the production of butter and cheese;

2) Conduct experiments in the planting of trees for timber and for shelter;

3) Conduct any other experiments and researches bearing upon the agricultural industry of Canada which are approved by the Minister.

Extension and Technology Transfer

First, it is safe to assume that in 1886 neither farmer, researcher, nor extension worker would understand the phrase "technology transfer." Extension yes, and demonstration, or verification trials. However, be that as it may, the early instructions were clear, making certain that the research was transferred from the experimental stage to the farmer as quickly as possible. Thus, the Act contains several references such as the samples of surplus of newly developed crops which are to be "disseminated among persons engaged in farming, gardening, or fruit growing." In addition, the Director or Officer at each farm "shall, for the purpose of making the results of work done thereat immediately useful, prepare ... at least once in every 3 months, a bulletin or report of progress."

A HUNDRED YEARS OF PROGRESS

The government officials who established the Experimental Farm Services system in 1886 invested in research for the future. The challege was a large empty pioneer country with seemingly unlimited potential but one in which progress would be inhibited by harsh climate, by a short growing season for crops and thus also forage for animals, by the great unknowns not only of soil problems and pests but also of markets. The development of Canadian agriculture to its position of importance in the economy of the nation is testimony to the judgement of the people who established the Experimental Farm System.

The benefit/cost ratio for agricultural research has been the subject of several reviews. There is a paper on the subject at this meeting. While admitting that some reviews are more subjective than objective, there is little doubt that agricultural research pays.[5] The Act of 1886 identified problems in animals, crops, and soils that required resolution. I promised to show what good research has achieved. Because we are a grain-exporting nation, it is appropriate that I should chronicle the story of wheat research. Before doing so, I shall touch on some other areas.

Stability in Agriculture

One of the most significant contributions that must be acknowledged is the stability in crop and animal production. While it is not correct to relate all the success in the development of agriculture to research on problems, it is my conviction that without the research, progress would have been much slower and substantially less advanced. The farmers, producers, and the industry have done the work: the scientists showed how. And not all of the research that assisted agriculture was done in Canada. A core of scientists, however, was available to translate research results performed in other countries. Canadian scientists did not invent irrigation but they did work out regimes for Canadian conditions. It has been said that the progressive farmers are still the best users of research. That is probably correct but the system has combined science and practical know-how and has meant progress.

When crises occurred, the research stations were there and solutions were worked out. In emergencies, this is still one of the chief roles of the research stations and one for which little credit is given in times when objectives must be set in terms of five years. There are many examples, especially when diseases occur, when scientists must change the direction of research and find out about the new diseases.

Soil Survey - Soil Conservation

The total land area of Canada is nearly 1 billion hectares but only 5 percent, about 44 million hectares, is improved farmland. An additional 20 million hectares could be used for agricultural production but most of this is located in areas of marginally suitable terrain and climate and is less productive than the land now farmed.

Many mistakes were made when early settlers took up homesteads in Eastern and Western Canada; abandoned farms are testimony to these errors. By now, however, most of the settled areas have been surveyed and resurveyed. This has provided much needed information for land use, for irrigation, for drainage, and for choice of crops. The current refinements are matching land use and potential with climate and weather as well as with sociological aspects of land use. When the Farm Service began, very little was known about chemical fertilizers. Over the years, the "rates and dates" experiments have sharpened into factorial experiments that demonstrate to farmers the economical application of major and minor elements to produce high yields and top quality.

Soil conservation is a very strong and important aspect of our research. There have been several serious drought cycles in Western Canada but the "dirty thirties" was far the most devastating. Wind erosion forced the abandonment of many farms and severely impaired the productivity of the prairie areas. Strip farming, cover crops, timely cultivation, and the corporation of straw and organic matter into crop land has reduced but not eliminated the wind erosion problem.

Animal Breeding and Diseases

The importation, distribution, and encouragement for farmers to raise purebred stock of various animal breeds was an early role for experimental farms. That action has left a heritage that is reflected in the reputation of Canadian stock in international markets. Although direct distribution and involvement in livestock improvement is no longer a major program, the Department still maintains a country-wide Record of Production Program. In the last 15 years, a major foreign cattle breed evaluation program has been carried in Western Canada. Nutrition and animal feeds have always remained a high priority program and, while it is not possible to relate rumen microbiology with increase in milk production, the milk production per dairy cow is substantially higher than 20 or even 10 years ago.

In poultry, one can be specific: a laying hen today produces 250 eggs at a feed cost of 1.7 kilograms per dozen eggs, whereas 25 years ago, the comparable figures were 180 eggs and 3 kilograms of feed. Twenty-five years ago, it took 13 weeks and 5.9 kilograms of feed to produce a 1.6 kilogram broiler. Today, it takes 7 weeks and 3.1 kilograms of feed to produce the same amount of meat.

Canada has one of the world's best records for healthy livestock. Aided somewhat by our cold winter climate, the scourges of tropical-type diseases are not important. Vets, however, have made significant progress on a variety of fronts inclusive of the following: the first diagnosis and subsequent elimination of dourine in horses in the early 1900's; the development of rapid and accurate brucellosis diagnostic technology initiated in the early 1940's and continuing now; major progress toward elucidation of the etiology and control of shipping fever in cattle; major progress in the field of embryo transfer and elucidation of the role played by the embryo in disease transmission; clarification of the economic significance of lymphoid leukosis in poultry and development of diagnosis of specific animal diseases; meat residue analysis techniques; bacteriological techniques; biologics production, and the maintenance of a solid and accurate livestock disease diagnostic base.

Crop Protection

A great deal of research effort has been placed on crop protection research: approximately 40 percent of the professionals. It is frequently said that crop losses from weeds, insects, and diseases amount to approximately 30 percent or 10 percent for each. Potential losses from wild oats in Western wheat farms have been estimated at 500 million dollars; damage to fruits and vegetables in yield and quality from insect attacks are obvious; vegetables and fruits rot in storage. It has been estimated, for example, that losses from stem rust in wheat would have been as high as $220 million a year if plant pathologists had not shown the way for resistant varieties. One worm does not contribute much weight to a vegetable salad but it certainly does put us off if we find it or, worse if we find half of one.

Plant Breeding

Canadian plant breeders, especially the staff of the Research Branch, have been singularly effective in breeding crop varieties suitable for Canadian conditions. To list them all would require considerable space. It is important to note, however, that the varieties are in use by farmers.

The rapeseed (canola) story is worth noting. Using modern techniques and equipment for analyses, breeders have changed this crop from one that produced a lubricating oil into one that produced a vegetable oil suitable for salad oil and margarine. In 1950, there were less than 170 hectares grown; by 1978, there were 2.8 million hectares.

In the horticultural crops, breeders have developed varieties that produce in Canada and thus reduce imports. Berries, apples, pears, peaches, tomatoes, turnips, cabbage, and cucumbers are some of the crops for which varieties have been bred. The special crops of peas, beans, buckwheat, tobacco, and sunflowers only occupy a few thousand hectares but the varieties grown are nearly all Canadian and developed by Research Branch personnel.

Ornamentals

One should not forget that ornamentals have made an important contribution to our Canadian way of life. Though expenditures in person years in ornamental research have not been great, the beauty and example of grounds at our Research Stations have made them show pieces and encouraged home owners--both rural and urban--to beautify their grounds. There has been a direct contribution as well in the creation of varieties suitable for Canadian conditions. Lilacs, rosy-bloom crabapples, philadelphus, rhododendrons, chrysanthemums, many species of shrubs and trees as well as turf grass varieties are some of the crops that have been bred. The Department maintains an arboretum at the Experimental Farm at Ottawa as well as one at Morden, Manitoba where woody ornamental introductions are tested and their means of propagation studied.

Food Products and Processing

The Act of 1886 stressed the importance of two main agricultural products--butter and cheese. Under the dairy division, and now in the Research Branch, cheese research is still a high priority for food technologists. The quality of food produced also became an integral part of the research at horticultural stations as did meat and egg quality and grading factors for animal research. In 1962, a national program of food research was begun with the establishment of the Food Research Institute in Ottawa.

Under Canadian conditions, extension of the storage life of fresh fruits and vegetables is paramount. Controlled atmosphere storage has permitted consumers to purchase good quality apples year-round. Other storage conditions preserve vegetables throughout the winter and well into spring.

Significant advances in food processing picked up by industry include: a process of dehydrating potatoes; a cooler that reduces cooking time for fruit and improves quality; a process for quality cottage cheese; a vacuum system for concentration of fruit juices, and a blanching process that reduces energy consumption.

Biosystematics

During those early years, systematic work formed only a small part of the duties being carried out under the Dominion Botanist and the Dominion Entomologist. In those years, they supervised all agricultural research involving insects, arachnids, nematodes, plants, and fungi. Many of the later organizations of Agriculture Canada originated from work originally carried out under their jurisdiction.

At the present time, the professional staff consists of 55 systematists and taxonomic research is comprehensive and world-wide in scope. Special emphasis is placed on taxonomic studies of insects, arachnids, nematodes, and fungi that are important in pest and disease management and environmental assessment studies as well as on native, naturalized, and foreign plants that are weeds or that can be utilized as food plants. The main roles of the Institute are the growth, maintenance, and utilization of the 17 million specimens, collections, and cultures in its National Collections, in its Department's Vascular Plant Herbarium, and in its taxonomic libraries.

The systematic collections are by far the largest and most comprehensive in Canada and have a wide influence on international biological research. The specialized taxonomic libraries are unique in Canada and have been designated as part of the National Library System. The collections and libraries are utilized by Institute staff to prepare taxonomic monographs, new classifications, and technology transfer publications and are reference sources that enable the staff to annually identify over 125,000 specimens through the Institute's National Identification Service. They are also used extensively for taxonomic research by other taxonomic workers both on the national and the international scene.

International Aid

Canada has had a long and close association with international aid organizations since their inception. Indeed, FAO had its beginning at the Quebec conference in 1945. Because food production is one of the major subjects used in aid programs, agriculture has been heavily involved and research becomes an integral part of the activities.

The departmental objective is "to assist developing countries to become self-reliant in food production." Beginning about 1970, the Research Branch began supplying agronomists on loan and, later, on behalf of the Department contracted with our government aid organizations to execute programs in

several countries. Two main programs considered outstanding have been a wheat production scheme in Tanzania and a rain-fed agricultural program in India.

While the amount of involvement varies each year, in 1980, for example, we sent 20 missions involving some 140 person months to 13 countries. In addition, scientists are encouraged to carry transfer of work programs at international centers and directors have been on loan to help organize research. Some of the latest agreements for the exchange of scientists have been with China, Israel, and Romania.

Wheat

"There is probably no agricultural product of more importance, or more variable as to supply and demand, and consequently more subject to variation in market value than wheat." A modern day economist? The Chief Commissioner of the Canadian Wheat Board? No--the opening paragraph of a thesis prepared in 1908 by E. S. Archibald.

David Fife, farmer at Peterborough, Ontario, received a tam-o-shanter of wheat from an uncle in Glasgow in 1842. From the plants that grew, he selected a strain or variety of spring wheat, Red Fife, that had enormous popularity in Canada and in the United States in the mid 1800's. It was a good yielder and perhaps more important was excellent for milling and baking. In Western Canada, however, it did not ripen in time to escape early fall frosts. The first challenge to the Experimental Farm Service, was, therefore, to find a replacement for Red Fife. As the Director stated in his report found in Bull. No. 4, 1887, "The question of early-ripening varieties of grain and especially wheat, is one of the utmost importance for the future of Canada."

In 1888, some 28 varieties of wheat were received from the London Corn Exchange. One Russian variety, Ladoga, was early and looked promising until enough seed was collected for bread making. Then its poor quality was evident. Not content with selecting from within present material, Saunders sought the desired variety by cross-breeding wheats with the object of combining the good qualities of two or more varieties. Let me remind you, ladies and gentlemen, that this was before Mendel's law of heredity had been rediscovered and publicized by scientists at the turn of the century.

In 1903, the breeding program started by William Saunders in 1888 had developed to the extent that assistance was needed. Without the consent of his son, Charles, William appointed him Dominion cerealist. Charles had, of course, assisted his father in making crosses in many crops. He carried on the work with steadfastness and zeal, just as the boss knew he would.

The garden note books that are in the writer's possession show that Charles applied sound scientific principles in the selection of varieties.[6] Among varieties or kinds under test were several strains from the cross Hard Red Calcutta x Red Fife. The crosses for this hybrid had been made at Indian Head by Percy Saunders in 1892 and two strains under the name of Markham had been sent to Ottawa. Charles had these two strains, Markham A & B, in his garden in 1903. The notes show that selections were not to be retained unless they were earlier and stronger than Red Fife.

Saunders had set his aim as having wheat earlier and stronger than Red Fife. Earliness was easy to measure because he would have check plots of all standard varieties growing side by side. The gluten strength was determined in the winter time by carefully chewing a number of kernels of each of the samples to find which one made the best gum. In those days, Saunders did not have the apparatus for making the small loaves which he himself developed in the years 1906 and 1907. Therefore, the first selection of Markham B which became Marquis was made by the famous "chewing test." There are people who still tell the story of the spot on the wall where Saunders threw the gum and verified the amount of elasticity by the stretching of the gum as it hung from the wall.

The rest is history. The first seeds of this selection planted in 1904 produced 12 plants. From then on, seed was carefully saved and increased and eventually samples of the variety were sent to the Western Stations of Brandon and Indian Head where plots and then fields were increased. In all of these tests, Marquis yielded well with plump well-filled kernels. By this time, Charles Saunders had developed a system for baking small loaves of bread. Again Marquis had super "loaf volume." In the fall of 1908 when a disasterous fall frost went through the West, Marquis had matured but Red Fife had not. This was the clinching evidence in favor of further distribution. In 1909, four pound samples were sent to farmers in Western Canada. It is from these samples that the wheat spread rapidly in Canada and in the United States and became what it is today--the standard for quality. This means that as many as 16 million acres were planted in Canada and 12 million acres in the United States.[7]

By the year 1923, Dr. L. H. Newman had succeeded Dr. Charles Saunders who had resigned because of poor health. In 1926, the early-ripening Garnet wheat was distributed by the experimental farms. It rapidly became popular because of its earliness in the Northern parts of Saskatchewan and Alberta. However, it was not favored by the millers and eventually had to be downgraded. In 1928, another early wheat, Reward, was introduced. It lacked yield and did not become popular. It did win world championship prizes for many years, however, because of its large plump kernels.

It would not be fair to leave the picture of wheat breeding without some reference to other areas of Canada because we grow many kinds of wheat and they are localized in certain regions. In Maritime Canada, we have mostly feed wheats, both winter and spring. In Ontario, we grow soft white winter wheats. For many years, we used varieties such as Cornell 595 or Dawson's Golden Chaff which came from the United States. But Canadian plant breeders

also developed varieties such such as Talbot and then the magnificent Fredrick variety, a high-yielding, large-seeded, low-protein wheat which gained such popularity that plant breeders were concerned that disease susceptibility would create a potentially dangerous monoculture. In Western Canada, there is a small acreage of hard red winter wheat and there, while early Russian varieties or varieties from the United States were first used, Canadian plant breeders developed Winalta, Norstar, and Sundance varieties which are high-yielding and top quality. In durum wheat Canadians have changed the variety picture completely, breeding a new standard and several new high-yielding varieties with larger kernels, greater gluten strength, and desirable color.

THE FUTURE

The federal government has recently published a discussion paper on the future development of our agri-food industry. As a starting point, the strategy looks to where we are now and where we could be by the year 2000. The Canadian agri-food sector has a unique opportunity for growth from now until the end of the century and beyond. World food requirements are growing at a rate that will put unprecedented pressure on its ability to produce food. Canada has the land, people, technology, and capital to increase by two-thirds the output from the agri-food sector. An opportunity, however, is not a guarantee. It is clear that there is an extremely bright future for our food and agriculture sector provided barriers to production can be overcome. In the 1980's, the agri-food sector will face both increased competition and demand and will become more dependent upon R&D to maintain its efficiency and ability to adapt to new and different challenges. The nature of the research is such that Agriculture Canada must provide the required leadership and coordination.

The strategy for mission-oriented research calls for more fundamental research in biology and engineering to provide answers to practical problems faced by producers and processors. An increased effort by both the public and private sectors will be needed to meet these challenges in Canada and abroad. Some specific areas of research include:

1) Land and water resources: The strategy highlights the need to study the soil and water problems of the Prairies, possibly by establishing a special centre there, and intensifying this research elsewhere in Canada. We must conserve and update the cultivated land, add new land to cultivated acreage, and develop better soil management practices.

2) Energy: Conservation and the development of new energy sources must be pursued more vigorously.

3) Animal production: Disease and insect control, reproduction problems, and feed efficiency are among the areas that could be improved with increased research.

4) Crop production: Finding new, hardy, fast-maturing crop varieties and improving cultural practices remains essential to expanded production. In addition, integrated pest control programs are needed to reduce dependence on chemical pesticides.

5) Basic research: Some promising areas include nitrogen fixation of cereals, genetic engineering, somatic hybridization, and cryo-preservation.

6) Food processing: New foods, new processes, and energy conservation are key goals to be explored, possibly requiring the construction of new research centers.

7) Northern development: Most of Canada's untapped agricultural land is in the North. Farmers will need new crop varieties and management techniques to move into this area successfully.

8) International: Agriculture Canada is a major source of professional and technical expertise in the agri-food sector. As such, and as a federal department, it contributes to Canada's Overseas Development Assistance Program supporting other agencies or carrying out cooperative projects on its own that can lead to complementary mutual benefits.

I said at the beginning that I would answer the question "What good has the Experimental Farm Service been to the practical farmer." In wheat production alone, it has been estimated that returns for research dollars spent have been of the order of 225:1. One could hardly ask for better returns on a commodity that is of such importance to Canada.

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HIDDEN OBSTACLES TO CREATIVITY IN AGRICULTURAL SCIENCE

by

STANISLAUS J. DUNDON

Creativity is expected of science today, especially in the service of fundamental human needs. The agricultural sciences are faced with the satisfaction of the most serious human needs, both short term, the providing of adequate food for the world, and long term, doing so in a resource-sustainable manner and in ways that let the rural poor share in the food.

In the face of a record of significant agricultural creativity, the public seems not to be grateful, nor do scientists from outside of the agricultural field. The public finds fault, urges the establishment of commissions, sits on the commissions, and writes harshly critical reports, urging that agricultural research model itself more after the fields of the critics and urges increasing the money devoted to competitive grants.[1] The spirit is definitely "What have you done for us lately?" In an exercise of a kind of hindsight, many critics, not seeing done what they would like to have done, suspect that some dark force must have been operating to prevent the obvious (namely the critics' own favorite project) from being attended to.[2] But in sifting through all this criticism, one does encounter some significant areas that do seem unaccountably neglected. Indeed, the recent Office of Technology Assessment's review of the United States Food and Agricultural Research System (OTA, 1981b), although intending to be only a review of research management and not of its substance, could hardly have been thought necessary if there were not some sense that something or other is not being done.

Those who have responsibility for doing or managing agricultural research know only too well their own serious list of obstacles to research freedom and breadth. The political and budgetary afflictions of the agricultural research system are abundantly on record (Ruttan; Wittwer; Hadwiger; Hardin; NSF). Indeed the OTA (1981b) review shows a not very generous federal support of agricultural research, in these times of inflation.[3] Given this clear record we can assume that those who are experienced in the political process and are partisans of good agricultural research will do what they can when any constructive action becomes politically feasible.[4] These external and publicly well known obstacles to creativity may be the major source of agriculture's problems. But they are not ones about which an historian and philosopher of science has much to offer.

There is a second type of obstacle which it would be the task of the historian and philospher of science to unearth. These would be obstacles which impede the humane potential of agricultural research, precisely because that research is done by a community of highly committed, thoroughly trained, and mission-oriented researchers, working in an hierarchical set of institutions of impressive intricacy and venerable antiquity. These would be obstacles to which the most passionate and

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productive scientist might willingly subject himself, but of which he/she is probably unconscious, which are often maintained and defended in the name of science itself.

In this introduction I cannot convince the sceptical that such obstacles exist, or that the effects of such hidden internal and almost unavoidable obstacles are very significant. To the doubters, I can only offer a dialectical reasonableness for patiently considering the possibility. You are already doing whatever you can about the obvious and changeable. If there were any hidden obstacles you would not have done anything about them yet, and any effort at improvement ought to start with most promising areas, i.e., the areas to which you have not yet directed any attention, the hidden areas. Fortunately, many of the problems in agricultural research begin to make sense because they fit a pattern discovered in the history and sociology of innovation in all applied research areas.

My procedure will be the following: I will cite examples of problems in agricultural research which suggest the existence of obstacles. Then I will attempt to create some unity in the problems we find around the concept of a scientific and/or technological paradigm. Then I will underline the potential and actual exclusionary effects of a technological paradigm. I will try to solidify the contention that such a paradigm exists by showing its exclusionary activity relative to alternatives gifted with inherent theoretical attractiveness. After trying to uncover the source of the exclusionary power of the paradigm, I will suggest some means to reduce its power.

PARADIGMS IN AGRICULTURAL SCIENCE

As applied science, agricultural research is practically indistinguishable from technological research. Sociology of technology is a fairly new field and has done relatively little in the area of the sociology of agricultural research (Gaston; Storer, 1980). Nevertheless, my direct experience with agricultural researchers, both active and retired, convinces me that suggestions by scholars such as R. D. Johnson, Tom Burns, and Edward Roberts make reasonable the hypothesis that research in a mature mission-oriented institution will be in the form of elaboration of a paradigm which Johnson takes from Thomas Kuhn and applies to technological research. In essence, the technological "paradigm" will be the outcome of the discovery or importation (technology transfer) of a new tool that serves some aspect of the mission so well that much of the research of the institution becomes an effort to elaborate that tool, or tools of a similar sort, in the pursuit of the goal. Eventually, that successful tool which was successful only with respect to one goal of the mission-oriented institution may come to dominate the institution itself, as its exemplary success, its pride and joy. The earliest history of agricultural science in this country shows the pattern in the very serious mission of remedying the declining fertility of northeastern soils (Rossiter, 1975). Fertilizer research and regulation became the dominating work of the first agricultural experiment stations. The political wisdom of exploiting a

successful tool was not lost on astute experiment station directors (Rosenberg). Within USDA a similar pattern is evident in the effect of the discovery of copper fungicides on the Plant Pathology Section (Galloway). More recently, the discovery, 2,4-D, is a dramatic example of a stunning, almost explosive impact on a research area (Peterson). Here the sweeping influence of this technology for weed control demonstrates that there is only one "institution" for agricultural research, an establishment which includes both the USDA and the agricultural colleges. Many new compounds were discovered and much fine tuning of herbicides ensued. But clearly a paradigm had been established for applied weed science. Work within a paradigm is dynamic, directed and, due to past success, colored with optimism and usually backed with administrative support. It is, therefore, rewarding to the scientist who contributes to it both intellectually and in his/her career.

Paradigm as a dynamic compass:

Peterson recounts how in 1944, two Beltsville scientists applied 2,4-D to dandelions on the lawn there. The two, John W. Mitchell and Paul C. Marth, then showed the results to E. J. Kraus of the University of Chicago, who had been working on 2,4-D in a secret military herbicidal program. In disbelief, Kraus dug up the remnants and found that even the roots had died! In the following months they demonstrated a 98% kill of clover in golf turf, leaving the turf untouched. Kraus' disbelief is a measure of the confidence which replaced it when the proof was seen. The path ahead was clear, not in the sense that all was solved but in the more delightful sense for a researcher--a whole set of problems of new applications, new compounds, limitations on use, toxicity appeared as the enthralling work of persons who had a valuable agricultural tool under their care. An example, perhaps a trifle excessive, is Kraus' behavior when, after some months of animal tests, he announced that he had consumed one-half gram of 2,4-D each day for three weeks without ill effects. The whole subject of weeds blossomed as an area of study now that there was something the researchers could do about them. In 1943, the USDA Bibliography of Agriculture showed 49 citations under various designations of "weed;" in 1949 there were 600 (Peterson). While clarity with the success of 2,4-D indicated the exciting path to be followed with many new discoveries to be made, so also did it cause other approaches and topics to get crowded out.[5] There is nothing surprising in this tendency of a scientific community to exploit as thoroughly as possible an area in which a great success has occurred making that general area, contact herbicides in this case, into a guiding paradigm generating a large body of literature and, at the same time, focusing research attention upon it. This is how progress is made; narrowing of attention is productive of progress.

Research Efficiency:

The beginning of a new research project will normally be a search of the relevant literature. We might guess intuitively that each researcher will have definite limits to how much time and how many sources he/she can consider in this preliminary search. In literature searches and information-retrieval there exists the problem of the *de facto* limits of

literature searches. Most researchers, therefore, are able to cite only five to eight journals in which they could publish their research and only a few more from which they would hope to obtain information for research. Although it is estimated that only five to ten percent of researchers would use computerized data bases, even those who use such bases encounter, perhaps unwittingly, additional selectivity. The data base will include 100 percent of the articles of only a restricted list of journals, those devoted specifically to the topic area listed. A larger number of cognate journals, perhaps three times as large, will be spot listed, with only one in ten articles being referenced. "Relevance" will be the determining factor, which implies that the <u>relevance bias</u> of the selector will operate. Two factors in that bias are <u>intuitive</u>: <u>what</u> the selector knows to be relevant because of his/her knowledge of the subject itself, and what the <u>community of scholars</u> being served is working on.[6] <u>Both of these biases are likely to be paradigm-affected.</u>

But even if there were no such biases in the reference selector, an even more strongly paradigmatic effect, discussed by Kuhn and elaborated at great length and in many places by Derek de Solla Price, is the manner in which research gets published in the first place. Kuhn indicates how the dominant paradigm in the exact sciences controls publication access, and de Solla Price defends this "elitism" by editors as an absolute requirement of any reasonable efficiency in science. Earlier, Storer made similar defenses (1966). The function, after all, is to assist the researchers in finding relevant information not burying them in an infinity of material. So it is not a matter of caprice that agricultural editors must follow the same practice, as pointed out by Buttel. Buttel notes that this kind of selectivity is unfortunately also based partly on the research trajectories of the editors (which may be somewhat out of date) established while they were active. And this is found to be the case in agriculture as well (Lacy et al.). Buttel makes the point that this is a selectivity which, while demonstratable, is not to be attributed to a kind of conspiratorial conflict of interest as implied by Hightower. But for its very honesty it is a potent force which can affect even prominent agriculturalists.[7]

<u>Disciplinary Origin of Paradigm Effects:</u>

Kuhn suggests that the most favorable aspect of a new challenging paradigm which eventually wins the allegiance of the scientific community is not that it solves all problems, but that it promises a broad range of exciting problems as potentially solvable by the diligent elaboration of the theory which is the heart of the paradigm. It is perfectly natural that applied scientists be drawn to two things implied in their name: some paradigm which <u>works</u>, i.e., whose application produces successful and highly <u>appreciated</u> results, and, secondly, gives them the opportunity to develop and demonstrate their own <u>disciplinary</u> skills. The entomologist, for example, is a scientist <u>who enjoys deepening</u> and elaborating his/her detailed knowledge of the life behavior and relationships of insects. Any idiot can squash a bug. But the precise control of insects, using detailed knowledge of relationships among insects, and attaining environmentally

benign methods, this is the work of high science. Consequently, one would expect that IPM would gain in favor with the discipline of economic entomology. On the other hand, eradication, or efforts which seemed aimed at the entire population of some species, could become too easily identified with the cruder notion of "squashing the bugs," and thus declines in favor with the discipline. And so it seems to be happening, according to Dr. Knipling, advocate of Total Population Management (TPM) for certain insect species.[8]

Management Effects of Paradigm Existence:

Just as successful paradigms produce and are reciprocally fortified and made efficient by dominance of the disciplinary literature, so also the education of the student and the laboratory equipment he/she is trained on is determined by the dominant paradigm. These are the major institutional responsibilities of the research administrators. Therefore, they too are affected profoundly by the paradigm. By definition, on-going mission-oriented research includes the goal in the paradigm so that new goals pressed on the institution from the outside will appear foreign not only to the scientific paradigm but also to the concrete equipment and personnel orientations of the institution. Hence, we cannot be surprised at the apparent paradoxical behavior of those who carry budgetary requests from research administrators to Congress. Both congressional staff who act as in-take officers for institutional lobbying for research support and administration specialists (OMB) dealing with agricultural research remark emphatically on the fact that the official representatives of public agricultural research start, and very nearly confine, their budget appeals to program maintenance and increases to cover the cost of inflation. Although they know that appeals based on exciting new needs and new and promising break-throughs would be politically more effective, the administrators do not resort to these. The effect is the appearance of a luke-warm appeal.[9] As often as not, it is Congress which suggests special projects with special funding for research and OTA (1981b) implies that USDA gets less research support simply because it asks for less than it could get.

AGRICULTURAL PARADIGMS AS EXCLUSIONARY

The genesis of a paradigm in its early stages in which promising applications and elaborations of the original innovation or discovery is followed by the concentration of a discipline around that paradigm. The fact that the discipline is the training field for new researchers suggests the potential for exclusion of research from outside sources and paradigms. The example of weed science is instructive. Prior to 2,4-D there was really not much of a paradigm in the field and, hence, it was really quite open to innovation; it is instructive, however, that the innovation is really a case of technology transfer, for the compound had been under study and production as a growth regulator and as a potential military weapon for crop destruction. The accidental killing of plants by overdose of the growth regulator suggested to those in another area, weed control, the possibility of deliberate overdosing. Can we look forward to a similar openness to new technologies to fit new needs as they arise?

We need to consider for a moment the openness of an institution, as large as the USDA or as small as a single department in a land-grant university which already has its analog of a successful herbicide. Edward Roberts shows how resistant, even intolerant, to innovation are major technological firms, whose very business is technological development, citing the example of a single major firm in Boston that drove off one by one more than 40 innovative thinkers who eventually set up 33 successful small R and D firms which eventually grossed more than twice the income cumulatively than that of the parent firm. Tom Burns shows how anti-innovative all institutions inevitably become. Empirical evidence indicates that, in a sampling of cases, institutions and individuals in them in the area of agriculture share the common traits of applied science institutions in general: The flip side of efficient exploitation of a successful paradigm is an exclusionary tendency toward new tools and new goals.

In trying to get some background on why the damage done by nematodes to California citrus orchards was not as extensive as had been predicted by an expert from one large California land-grant university during the 1977 cancellation hearings for the nematicide DBCP, I called the Department of Nematology at another large California land-grant university. The young assistant professor who spoke with me told me about several alternatives, indicating that most of the alternative pesticides were extremely toxic and hence little used by farmers. He mentioned "management" as an alternative. I was curious as to how one "manages" nematodes deep under a permanent citrus plantation. To my question, "What does 'management' imply for nematodes? he answered, "I don't know, we only do chemicals."[10]

What chance would an innovator have had, in 1977, in obtaining time and funds to do a study of management alternatives to chemical controls in that department of nematology? It is a speculative question and is best answered with another piece of history. From 1934 to 1937, a young entomologist, Edward Knipling, conceived of transfering a technology from pure science research in Mendelian genetics (the breeding and attempts to stimulate mutations in the Drosophila fruit fly) to an applied science field. In those days every undergraduate course in biology would mention the fruit-fly experiments and it occurred to Knipling that the laboratory technology of deliberate inducement of mutations would be quite amenable to transfer to an experiment station environment with its budgetary and personnel constraints. It was an imaginative project, and unfortunately, remained in Knipling's imagination for more than a decade. His idea was to induce mutations in the screw worm, perhaps producing one which had no spines with which to burrow into hapless cattle, just as Drosophila breeders had produced a wingless fruit-fly. But not until 1947 when Knipling became Head of the USDA's Division of Insect Pests of Man and Animals was he able to get the project going, one aimed at producing sterile but sexually active males. The eventual successful eradication of the screw worm is a matter of history. What is not well-known is that in spite of two successful trials in isolated areas, off-shore islands, Knipling and his immediate superior were reluctant to start the national program fearing the great cost ($2 million in 1955) and fearing the impact of possible failure associated with such a "bizarre" project as altering

the sexual lives of insects. Utimately, a Florida cattleman convinced them that the economic argument was overwhelming. The annual loss to the screw worm in Florida alone was $10 million. A fly breeding plant was built and in two years the screw worm was eradicated. What we have here is not the anti-innovativeness of an intrenched paradigm, but merely bureaucratic conservativism.

It is instructive to observe the difference between this example and that of 2,4-D, also a penetration of a vacuum. In this case the introduction of a paradigm where there was none to resist it was swift and conclusive. The sterile male program for screw worm was much more cautious. A significant difference is that the 2,4-D was a commercially exploitable product, developable into marketable products in a relatively short time-frame. On the other hand, the initial and subsequent applications of sterile fly techniques was dependent on public funding and region-wide publicly subsidized application. The institution "marketing" the research would have to bear the political risks of failure and that institution, the USDA, is more than adequately sensitive to those political risks. Knipling feels that the aversion to risk in the case of relatively high cost tests of Total Population Management in the control, for example, of the Fall Army worm ($5 million) will continue to have the impact of preventing the acceptance of a TPM paradigm and, given its consequent permanent "theoretical" condition, it is not surprising that peer reviewers for disciplinary journals reject his articles on TPM as "too theoretical."

What we see in those two examples is that in the institutional setting an innovation will encounter resistance or find acceptance according to whether it fits the needs of the social system which is the institution. In the case of 2,4-D neither did researchers have a project of exciting and challenging proportions, nor did the managers have a tool to offer its clientele. 2,4-D supplies both. It was in. TPM, on the other hand, inherits all the burdens of the first sterile screw worm fly program, plus the fact that there are workable tools and research projects in the hands of the social system, i.e. IPM and various pesticide programs. So two distinct kinds of obstacles are tied together there--the riskiness of a very expensive kind of research and the ruling position of the rival technology.

Donald Schon attributes institutional resistance to innovation which he calls "dynamic conservatism" to the interplay of three factors: social structure, theory, and technology. The persons in the social structure of a research institution do not need to be reminded how the direction of research is affected by the hierarchical system. Those in power are consciously doing the controlling, and those under command feel its impact intensely, both in curtailing initiative and in rewarding it when it is perceived by superiors as good. Like the political obstacles to research creativity, I wish to pass over the limitations which come from this overt control by the social structure. Rather I want to focus on the range of obstacles that arise when agents in the structure, whether superiors or colleagues, believe that the tight interplay between theory and the tools it produces are "scientific" in the exclusive sense, i.e. in the sense that "good science" underwrites its current paradigm and disapproves of rival alternatives.

N_2 Fixation Technologies:

One means for detecting the existence of paradigm-generated resistance to innovations of a specific sort is to choose an area where the bureaucracy is committed to the discovery of a new technology and where the research direction seems not to follow any obvious bureaucratic approach, e.g. less risky or expensive. In the "Pound" report considerable emphasis was placed on the need for N_2 fixation and photosynthesis research. Little of this work was then underway in USDA. Two routes to enhancement of biological nitrogen fixation quickly emerged. Summarizing some of these routes suggested by the National Science Foundation and others, the Office of Technology Assessment (OTA, 1977) found that selection of non-conventional native species with nitrogen fixing ability especially for Third World use and, referring to an earlier NSF study, extension of rhizobial-based nitrogen fixation ability to non-legumes and transfer of genetic information for N_2 fixation and necessary associated reactions to higher crop plants. But the high technology conclusion is obvious:

> There is little hope of attaining either of these goals until cell culture techniques have been improved. Furthermore, they will involve recombinant DNA research that, in turn, will require special containment facilities. (OTA, 1977).

In the OTA recommendations the process of collecting native N_2 fixing species, relatively cheap by comparison to the gene manipulations, falls by the wayside. The DNA research is suggested for the bulk of the budget and in the concluding passages it alone gets honorable mention; collection germplasm is ignored. In fact, USDA continued its research on conventional legumes. At a conference sponsored in 1980 by OTA, however, none of the germplasm specialists assembled there had received USDA or land-grant university support for their research. As Noel Vietmayer pointed out to me at that time, of five leading scholars who have devoted attention to Third World native species for N_2 fixation, three have become curators of botanical museums, one left a land-grant university to work for a privately funded study in Texas and another has gone to work for Rodale.[11] Since the 1977 OTA study we know what has happened to DNA research outside USDA, although it has produced no breakthroughs in N_2 fixation. In part because of the promise of patentable results, the discipline has exploded; research, equipment, students, and graduate programs in this country have been formed. Although this outcome has the appearance of being a new paradigm itself, it should be contrasted to the native species approach. The DNA research is typical United States based laboratory, home-campus research. Highly specialized articles are published in disciplinary journals, leading to promotion in publish-or-perish disciplinary departments, and remunerative relationships are established with an appreciative clientele. A composite picture of the germplasm collector, on the other hand, drawn from the OTA workshop is that he/she is funded by the Mennonites, out slogging in the jungle or on mountainsides, finding promising new species or adapting them from native farmers and running tests on them, studying the social and economic factors needed to integrate the innovations into village farming systems, writing in interdisciplinary journals and ending up as curators of botanical museums (OTA, 1981a).[12]

The Professional Paradigm:

The previous example suggests something quite peculiar. Although genetic engineering is a perfect example of an exemplar in laboratory technology spawning a paradigm, no applied agricultural science technological exemplar was produced. On the other hand the excluded paradigm, native species exploitation, has produced considerable success in limited areas in the Third World, and organic farming in this country is demonstrating an ability to sustain nitrogen levels and commercial farm economy by putting nitrogen fixers in the rotation (USDA, 1980). It is clearly not a question of two technological paradigms, each with its favored technology, one favored by the establishment, the other definitely not. The establishment simply does not have a nitrogen self-sufficiency technology.[13]

From the condensation by Masterman (1970) of Kuhn's many meanings of "paradigm" and Johnson's application to a technological paradigm, I choose two to explain the peculiar ability of a non-existent technology to exclude an extant and successful technology from becoming the object of research and exploitation by the establishment scientific community. The first is "metaphysical paradigms" to be discussed later, and "artefact paradigm."

Although Johnson does not develop the "artefact paradigm" aspect in explaining technological paradigms, in this kind of paradigm Masterman includes concrete things like the books, laboratory equipment, practices, and so forth. It is an important aspect of technological paradigm, for while it is true that a soil fertility specialist has a goal which is a large part of his paradigm, what kind of scientist he is will differ a great deal if he works with manure, legume rotations or recombinant DNA. Tied up in the kind of research equipment and ancillary "pure sciences" of which their use presumes a mastery is the sensitive issue of scientific self-image, as well as the life styles and reward systems available to practitioners of different sciences. In the maze of reciprocal cause and effect relationships which can exist between "artefact paradigms" and this scientific self-image, reward systems and life styles are two which have obvious obstacle-producing capacity with respect to innovations. A technological exemplar can create an "artefact paradigm" which determines what kind of life style and self-image the applied scientist has. Reciprocally, if he/she already has that self-image and life style, it can affect what kinds of technologies get developed. It is clear that Justus Liebig's exemplar, chemical fertilizers, in the field of soil fertility studies, caused American scientists legislatively mandated to study "soil science" in the early experiment stations to identify themselves as chemists (True). Indeed, chemistry is what they did. Soil science was not dirty-boot work in those days; its early practitioner could live at Harvard and have one or two Irish maids depending on how many lab assistants he was willing to hire (Rossiter, 1975). On the other hand, Roland Thaxter, the first plant pathologist at the famed Connecticut Experiment Station insisted on being called a mycologist, but plant pathology is what he did, right in the rotting potatoes and mildewing grape vines which he personally sprayed for farmers, until he could finally get back to Harvard (Horsfall). Horsfall's account is a poignant picture of how scientific self-image affects the agricultural scientist. I would like

to combine the "artefact paradigm" with these reward system, life style, and scientific self-image components into a single loose unity which I will call the "professional paradigm." If a group of scientists are assigned the job of developing nitrogen self-sufficiency for a farming system, it matters a whole lot to the kind of technologies which will be attempted how they answer the questions: Where do I live? What kind of equipment do I use at work? What kind of sciences does that suppose I am master of? How do I know or show that I am good at the work (by publishing)? Previously successful technologies in that field may have made a certain self-image, life-style, and reward system possible, but there are obviously going to be obstacles thrown up to the research into a different technology which conflict with the professional paradigm. And, indeed, the professionals who decide to put the goal above adherence to the professional paradigm may find that the institution which assigned them the task will not support them. Thus one finds effective work in international agricultural development largely dominated by faculty so far along in their careers that the reward system cannot threaten them, or else by professional "gypsies" without institutional ties (Conklin). Relevant work of nitrogen fixation by native species is simply not at home in the professional paradigm of establishment agriculture, for it would not lead to publication fast enough, not lead to publications of the same technical sophistication and disciplinary narrowness as recombinant DNA research, and would pull the researcher away from the professional "scene of action," a syndrome existing in other fields of agricultural research as well (Conrad).

<u>Strength of a Professional Paradigm as an Obstacle to Innovation:</u>

1982 may go down in history as the year of the great agricultural crunch, with the largest percent of farm-loan delinquencies in recent history and a flood of foreclosures expected for next year. Because of the cost of money and declining returns on capital intensive approaches, even the USDA is advocating that increasing the size of an operation may not be the way to go. Let me impose a utopian image on this disaster scene: extension agents all over the country, three years ago, anticipating the difficulty, prepared farmers for the crisis by means of a package of material and strategy preparations so that they have on hand their own farm-produced means of reducing fertilizer costs to near zero with little or no cost in terms of reduced yields. The reduction in production totals that come from the on-farm preparation of organic sources of fertilizers pushes prices up and the day is saved.

Instead, this spring and summer saw the publication of a series of articles by William Liebhardt, a university soil scientist who in early 1970 started doing fertilizer-response studies on Delaware soils and began to see a pattern of over-prescription of fertilizer, especially phosphorus(P) and potassium(K). The articles showed that many university and commercial soil testing laboratories tended to over-prescribe, to the tune of about $24 per acre of materials, with many labs doing far more harm to farmers' pocketbooks. In general the university labs were more consistent and conservative. Most savings could have been made in the area of P and K but recommendations for nitrogen, notoriously difficult to test for, should include field histories

to allow for significant residual effects of previous legume crops. The legume contribution was frequently underestimated or ignored. A smaller number (20) labs recommended for micro-nutrients and averaged about $22 in excess material per acre (Liebhardt, 1982).

At first glance this might have seemed like the exposé of some great scandal inside the scientific community of agriculture. But, in fact, a friendly reaction was experienced from among academics in soil science including those involved in the practical business of soil productivity maintenance. Many of them were well aware of the difficulty of doing good soil testing, an historic problem from which extension and State Agriculture Experiment Stations (SAES) had suffered in the past. In fact, at the recent meeting of the Soil Science Society in Atlanta great interest in techniques for reducing fertilizer use and input costs for farmers was manifested. Universities, especially Kansas and Nebraska, had been doing studies which showed consistent overprescription by commercial labs. In some sense confidence in common soil-testing technology as a farmer's aide had already plateaued, although testing is still a robust technology.

As a dialectical device let me return to my utopian vision of agriculturalists having prepared farmers three years ago for this year's crisis, and ask: Why didn't the utopia happen? It would seem an unfair question involving the 20/20 vision that always accompanies hindsight. The point is that the science needed for this missed opportunity already exists, although much more science is needed and some is being done at the moment (USDA, 1980). The science which was being practiced, however, was another matter. It was well-known, for example, that field calibrations are needed to make soil tests meaningful and reliable. But it is almost impossible for the professional practice of extension agents to help farmers attain economically conservative fertilizer recommendations via such calibrations, even if that were their traditional goal. Critics will jump on this and say, "Of course, input reduction never was their goal, output increase always was, and insanely so, even in the face of damaging crop surpluses." No one wishes to deny that conventional United States' agricultural research policy is oriented to "production agriculture" (OTA, 1981b). But before we find that as the explanation we need to take a closer look. The kind of soil productivity technology which extension and SAES could manage on their budgets and work style is home base and laboratory-oriented. Indoor work predominated in the past, according to Roy Simonsen, soil classification expert with decades of experience in practical and scholarly work on soils. When he started his graduate education at Iowa (Ames) he had already gained a good deal of experience in "outdoor" soil science in classification work. When he pointed out that the Iowa experimental control plots indicated that no fieds in Iowa needed any fertilizer, his director got the point immediately: no effort had been made to assure that the experimental plots were representative of the six or more basic soils types in the state. Simonsen indicated that to this day many universities have not seen their way clear to make this kind of arrangement so that there is some kind of relationship between what is done "indoors" and on campus fields and what is likely to be encountered "outdoors." Oddly, the skewing of plant and animal

nutrition studies due to a lack of a base-line knowledge of different native soil contributions was pointed out by an early advocate of publicly supported experiment stations (Miles). He would be disappointed to find a century later that SAES in general has not been able to overcome this difficulty and that practical soil productivity work tends to be indoor science, i.e. Liebigian science, chemistry in large part, and so considered by its practitioners who named themselves chemists as we noted. But it is only fair to say that this home-base orientation is as much compulsory as chosen. Liebig produced a paradigm which either produced or fit a working style (which might have occurred in any case) and became what I have called a professional paradigm.

It is clear what the attractions and necessities of this applied scientific paradigm are. Simonsen says that it is characterized by the conviction that "soil is soil" wherever it is.[14] That is, it is a negligible substrate, not of fundamentally passive character, but whose differential contributions from place to place could be neglected. Charles Kellogg, many years head of USDA Soil Survey, reportedly said, "I have been fighting the ghost of Justus Liebig for years." This comment was related to me by Cliff Orvedahl who worked under Kellogg for years and is a distinguished soil scientist in his own right. Orvedahl also indicated to me repeated examples of tendencies, both in the United States and abroad, of agricultural scientists to prefer the image of a uniform soil. Of course they know it is not true. They know that they are practicing a "Ptolemaic" soil science, much as schools of navigation find Ptolemaic astronomy still serviceable to instruction. The problem is that if one wishes to have a soil productivity technology which enjoys universal applicability one has to have a soil with universal properties. The universal tool, to be scientific, had to have the predictive success which is supposed to characterize good science, and the best way to make sure that yield reductions do not falsify the science and embarrass the practitioner is to cover the differences of soil by a large safety margin in the prescription. A whole new professional paradigm, including the sciences utilized at its heart, would be needed for cost-reduction oriented fertilizer use. Post World War II abundance of fertilizer fits well into the conventional professional paradigm and it effectively made low-input technologies irrelevant. Did that professional paradigm actually <u>exclude</u> rival low-input approaches? Certainly not, as far as farmer practice was concerned. But as far as institutional realities are concerned, it had to. To do anything else, to take low-input possibilities seriously would have meant admitting the sorry condition of soil productivity practices by the institutions and the investment of considerable time and money, upsetting the home-base work style, etc., all of which would hardly even come to mind for all its costliness.

In an earlier study Liebhardt shows that the deficiencies of the Liebigian model were apparently keenly enough felt to cause researchers to look for a more scientifically adequate basis for a universal concept of the soil. The pursuit of an "ideal soil" motivated the research which produced the Basic Cation Saturation Ratio (BCSR) concept (Liebhardt, 1981). Although the burden of Liebhardt's literature review and his own research is that there

is little empirical basis for BCSR, BCSR does lead to unnecessarily generous fertilizer recommendations and has been used by commercial labs as a theoretical justification. I think this is clearly a case of technology leading the science, but it would be completely to miss the point to see this as cynical cupidity overwhelming scientific good sense. The pursuit of the universal and its wedding to universally applicable technologies is a Western intellectual tradition which had no inherent evil to it. It may be an unfortunate intellectual tradition, for it takes the form of first reducing everything to science, and then reducing natural sciences to exact sciences. I think that BCSR and the concept of an "ideal soil" are part of that tradition. The fact that low-input technologies will have to be based on reversing the study of soil so that from an exact science it must return to a natural science may be the main obstacle in its path.

Professional Paradigm in a Dominant Institution:

The question is: In a dominant institution such as the USDA-Land Grant complex, can a paradigm shift occur, or in my terms will a professional paradigm permit a shift? . . . If the professional paradigm cannot accommodate the paradigm shift, where will change come from? That soil productivity technology, via fertilizers, plateaued during the 1970's is arguable, since the Green Revolution is strongly based on it and is still seen by many as a triumph of agricultural research. General soil science texts of the 1960's and 1970's in the United States show little awareness of any faults in the paradigm. One finds an almost fervent defense of fertilizer use and little or no discussion of means to avoid over-prescription of fertilizer.[15] Up to the present, it seems to me, the field-dominating character of publicly supported agricultural research and extension has effectively excluded the rival paradigm in spite of its economic superiority. It is this relationship between a professional paradigm and a dominant research institution which makes the question of paradigm-generated obstacles to innovation of such crucial importance.

THE METAPHYSICAL PARADIGM

I have cited some reasons for the non-appearance of cost-cutting technologies in our current farming crisis as being traceable to a rather narrowly focused professional paradigm of soil science. Other possibilities may exist and some of the audience may be able to testify to their reality. Some of you are aware that at least part of the cost-cutting technologies referred to are common to the practices of organic farming, especially the use of legumes. You also may be aware that Liebhardt's revelation of the soil testing inconsistencies was published in New Farm, a publication of Rodale Press, and that Liebhardt is now working a research director of a study of the dynamics of changes in soils during conversion from conventional to organic farming. Whether there is such a thing in agriculture as a metaphysical paradigm can be tested in the following way.

Metaphysical paradigms in science are fundamental commitments to what is "rational" and even what is possible. Kuhn says that these are so strong that they even affect what a scientist will see. . . . It is a fact that there are many large commercially successful, full-time, organic farms selling their produce through normal channels, most of whose operators were formerly successful conventional farmers before switching to organic approaches (USDA, 1980). It is a perfectly rational form of farming. Arguments that it is bad policy because "we cannot feed the world that way," to my mind, simply reveal that some kind of paradigm is at work, for it is not clear to me that conventional farmers are expected to choose their technological package on the basis of a world hunger ethic. The world hunger argument, it seems to me, is simply the effort to maintain a single paradigm. . . .

Metaphysical Paradigm as an Institution-wide Obstacle:

It is really not worth our while to try to categorize all forms of obstacles to research creativity under some form of paradigm. . . . Many scholars think they see such a thing, though they do not call it a metaphysical paradigm. Hadwiger (1982) sees it as a nearly irrational devotion to production, Dahlberg (1980) agrees, although he also sees many individual elements which I have assigned to professional paradigms. Eliot Colemen (1982) sees it as a kind of "dominance" mentality. One way to find a metaphysical paradigm would be to strip away all other sorts of obstacles, such as common institutional resistance to change, professional attachment to a specific technology, and see if there is anything left which seems to operate system-wide.

* * *

SOLUTIONS

To open the agricultural research establishment to innovation and end the exclusionary power of paradigms we might turn once again to the history of paradigm shifts in other technological fields. Johnson (1972) notes three ways this occurs, of which only one would respond to deliberate policy: transfer of technologies by agents, not agencies, (following Burns [1969]) who have been trained in that transferred technology outside of the recipient institution. Applied to agriculture that would suggest bringing some experienced agro-ecosystem agriculturalists from foreign countries, a point hinted at in OTA (1981b).

Roberts implies another technique which the dominant position of what is really a single publicly funded agricultural establishment would seem to preclude: competition from other research establishments. This has long been intuited by those who have pressed for competitive grants in agriculture and by those who recently fought the efforts to exempt agriculture from the effects of HR 6587 which requires 1.25% of USDA research funds to be available for private small business agricultural research. This is the conventional wisdom on innovation.

But I believe our sorting through paradigmatic effects in agriculture suggests, especially in the area of "metaphysical paradigms, that what may appear an irrational devotion to energy-intensive technologies in an energy-scarce day is the result of a whole set of institutional and work-style necessities. Only by changing these can we expect to find a home for innovation. A bright innovator from Kenya dropped in an academic department would be expected to publish narrow disciplinary papers if he expected to get tenure. In an experiment station he would have to produce results which satisfied the extant constituencies. With respect to cost reducing technologies, however, there is a chance, because farmers still do constitute a constituency, albeit declining. One thing which researchers will report is that it is a heady pleasure to see their inventions being put to use. A constituency is both a creative as well as a political necessity. Some innovation in constituency could hlep. An area already demonstrating this is IPM. Small firms that market advice rather than materials, substituting information for energy, as George Brown loves to emphasize, have become such a constituency for IPM research, a kind of research inherently more satisfying to entomologists than "squash-em" technologies. One could visualize such services in soil fertility as well.

But if my analysis is correct that institutional needs, disciplinary definitions of work, academic work-styles and reward systems, and the need of professionals for tools that work quickly and without too much detailed knowledge of the environment of application have been the real sources of anti-innovativeness, and not mysterious metaphysical paradigms, then it is to those "professional paradigms" our attention must be directed.

Footnotes

1. Perhaps most notable is National Academy of Science study (NAS, 1972), the so-called "Pound Report" after its chairman. A brief but devastating summary of its contents can be found in Science (Wade, 1973a and 1973b). Also explicit and many implicit deficiencies are noted in the World Food and Nutritions Study (NAS, 1977) and in Federal Support for Research in the Plant Sciences (NSF, 1979). Also even from within the agricultural research community we find echoes as in A Time to Choose: Summary Report on the Structure of Agriculture (USDA, 1981). Implicit in Report and Recommendations on Organic Farming (USDA, 1980) is the conclusion that not much research on a major means to reduce farmer input costs has gone on in the research establishment. Finally, a recent White House-Rockefeller meeting called for competitive research grants up to $100 million.

2. For a balanced and basically compassionate discussion of the conflicting pressures on agricultural research in a more "innocent" era, see Charles Hardin (1955); a stronger more recent view is in Hightower (1973) and approaches the strident in Van den Bosch (1978). From within USDA one hears that traditional views of "what is really serious farming" may be responsible for the neglect of research appropriate for small and part-time farmers, or due to choosing an economic perspective so far into the shadowy future that the economics of the growing significance of part-time farming is not seen (Interview with Howard Kerr, Beltsville Agricultural Research Center, March 1982). Many other attempts to understand restrictions in research were offered to the author from within the USDA but these may be best dealt with later.

3. There is no question but that Congress has not really responded to the needs for additional monies just to keep agricultural research laboratories and equipment in repair and up-to-date. Competitiveness for funds may have a lot to do with the inability of innovative projects to get started.

4. But there is a peculiar circularity in this problem. The author, in interviewing several officials of regional and state agricultural experiment station programs, found that the officials were reluctant to frame an appeal for congressional generosity on new needs like sustainability and world hunger.

5. In the Proceedings of the Third Annual Southern Weed Conference only a few years after the discovery of 2,4-D, every article except two deal with applications and testing of uses of 2,4-D. The conference papers and attendance lists show widespread involvement of faculty from dozens of land-grant institutions.

6. Interview, June, 1982.

7. The eminent soil scientist, Dr. Martin Alexander, related to the author that in the case of one very ascendant paradigm, no-till agriculture, his cautionary and sometimes dissenting articles would not get published were it not that he happens to be on the editorial boards of the journals in question.

8. In an interview with Dr. E. Knipling, USDA entomologist and pest control expert (retired), June 24, 1982. The ascendancy in publication channels of IPM related articles is, I believe, a fortunate manifestation of the preference of scientists for work which can demonstrate the refinement of action which comes from good science. It is a return to the wisdom pointed out long ago by USDA specialist and leader in economic entomology, L. O. Howard (1929, p. 139), of using precise knowledge rather than some crude "scheduled application" of a pesticide. However, in reference to the Total Population Management approach of Knipling, environmentalists should be careful not to overlook the fact that TPM in some cases may be environmentally much less damaging than IPM which will often require significant continuation of the use of poisons where TPM would not.

9. These impressions were reported to the author in interviews during the month of June, 1982.

10. The testimony in 1977 was by Dr. Armand Maggenti. He stated that ( ) acres would be lost at once and that in 10 years without DBCP areas in California's citrus region would become like stripped Mediterranean deserts. The occurrence in 1982 of one of the largest crops of oranges led to dumping, destroying, and abandonment of many tons of oranges. The neglect of the effect of many of the natural controls on nematode populations, including predaceous fungi, in making the prediction of the effect of the loss of DBCP is understandable, but I believe it is traceable to preoccupation with a single type of technology. See DBCP Cancellation 1977, Official Court Reporters Stockton, California, pp. 64-68 of the Transcript.

11. The five are: Richard Schultes at Harvard; Peter Raven at St. Louis Missouri Botanical Museum; Hugh Iltis, University of Wisconsin; Peter Felker (who left U.C. Riverside to work for a King Ranch-funded dry-land agricultural study), and Richard Harwood, now at Rodale Research Center, a privately funded program.

12. Although OTA 1981b (pp. 163-64) points out that there is a kind of ethnocentric blind side to USDA in reference to overseas agricultural work and that this results in a lack of funds for scientists who wish to go overseas, it has long been understood that the obstacle comes from typical campus reward systems and academic-discipline definition of appropriate work output. In addition the unwillingness of USAID to fund small projects means that innovators can often not get seed money to do pilot-scale projects (OTA 1981a, p. 70).

13. In hearings in the summer of 1982, co-sponsored by Congressman James Weaver, Chairman of the House Agriculture Subcommittee on Family Farms, Forests and Energy, and Congressman George Brown, Chairman of the House Agriculture Subcommittee on Department Operations, Research and Foreign Agriculture, the USDA Research Chief Kinney expressed reluctance toward a modest organic farming bill and Garth Youngberg, head of the organic farming program set up by 1977 legislation, was forced to admit that he had in fact been given duties which reduce the time he could spend on organic research by half. This, in spite of the fact that the first stage publication of the program "Report and Recommendations on Organic Farming" (USDA, 1980) was one of the most popular technical publications of USDA in recent years.

14. In an interview, June 22, 1982. Simonsen was also editor of the international soil science journal _Geoderma_.

15. There is a peculiarity in some of these texts, though. One finds little but quite profound philosophic discussions of whether there is such a thing as the "balance of nature" and whether it makes any sense for humans to hold back from trying to use as much intervention as necessary to secure adequate food supplies. It is the kind of philosophic polemic in defense of a technological paradigm which in science would never be found in a text, certainly not outside the preface, except in times of great stress under the attack of a challenging paradigm. Were the authors aware of some such paradigm? I think not, they were aware of the _Silent Spring_ threat, a fear that political interference, not on agriculturally relevant grounds, would deprive them of the only tool their profession had. In science "metaphysical foundations" of paradigms come to the surface during paradigm struggles, a revolution within the discipline. In technology, or at least in American agriculture, a politically generated metaphysical paradigm is possible. The sad thing is that this metaphysical foundation is now constructed and available to be used against agriculturally relevant challengers, such as low-input technologies. An effort to reduce fertilizer use will be seen as an environmentalist plot.

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AGRICULTURAL JOURNALISM AND THE DIFFUSION OF SCIENTIFIC KNOWLEDGE IN TWENTIETH CENTURY AMERICA

by

JOHN T. SCHLEBECKER

Scientific knowledge, theoretical and applied, has obviously been disseminated. Nothing less than effective dissemination would explain what has been happening in American agriculture, 1960-1980. Productivity per man-hour, per crop-acre, and per-animal unit has both risen and risen spectacularly. The over-all man-hours spent in agriculture fell from 15.1 billion in 1960 to 4.3 billion in 1979. The index of crops per acre rose from 93 in 1960 to 144 in 1979 and the index of animal products rose from 87 in 1960 to 107 in 1979.[1]

The many sources of this scientific information include not only the state and federal agencies but also private businesses which are increasingly involved in agricultural research. These, of course, include chemical and pharmaceutical houses as well as plant breeding firms. The Plant Variety Protection Act of December 24, 1970, gave plant breeders patent-like protection for their new varieties, somewhat like that which already was available to chemical and pharmaceutical firms.[2]

Dissemination of scientific knowledge from all sources almost invariably involved publications of the USDA Extension Service, the Experiment Stations, and the electronic media. From the farmer's point of view, or even that of an historical researcher, the volume of publications and broadcasts is gigantic. Still, not everything is equally valuable and, according to the reader's agricultural specialization, not everything is germane. The information explosion is just too much for the farmer, rancher, and agriculturist. They must either ignore most scientific discoveries or rely on an intermediary to sort them out.

In terms of science, the function of the agricultural journal is to cull the herd. Someone on the staff of the journal has to review the enormous amount of material submitted and then bring to the attention of subscribers the information which may be valuable. Most agricultural journalists are quite adept at hitting their mark since, for the most part, their subscribers are limited either by commodity interest, methodological interest, or geographic interest.

Advertisers support the specialized efforts of the journalists. Advertisers want to hit their audience and no one else. (Advertisements contain a surprising amount of information, even though it is always smothered in bragadoccio). So it happens that while reading the Guernsey Breeders' Journal one will hardly ever see anything, in ads or in articles, concerning swine husbandry. Obviously, the readers of the journal do not cancel their subscriptions because of this oversight.

Few are likely to be able to say just how many agricultural journals exist in the United States. The figure probably varies from week to week, if not from day to day. The '81 Ayer's Directory of Publications carries an index of "Agricultural Publications Grouped According to Classification."3

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In that index some journals are listed more than once, and some, like Hoard's Dairyman, are not mentioned at all. Neither time nor wealth permitted a computerized analysis of this mess, or the reasons for it. Still, counting along, there are about 600 agricultural journals published in North America. These range from the Iowa Agriculturist to Head, Heart, Hands and Health to the Canadian Tobacco Grower.[4]

Sometimes scientific information overlaps various interests. Discoveries in animal nutrition, for example, may be of value to swine, beef, dairy, and horse people. This is perfectly obvious. The journalists segregate the information according to the presumed interests of their clientele. The journals thus provide a service which has kept some of them in business for over a hundred years and promises to keep them in business longer than that. If a summary of the same Experiment Station Report appears in ten different journals, no harm is done.

Every journal has its own personality. There is no way of accounting for this. Apparently, like other institutions, agricultural journals pursue a life independent of the lives of the people who own and edit them. Journals rarely ever really change, except a little bit around the edges. When the lifestyle of the journal no longer suits its readers, the journal simply fails. This observation is derived not only from my doctoral dissertation of some 28 years ago but also from a more recent investigation of some seven or eight agricultural journals covering the years 1960 to 1980.[5]

The names of the journals reviewed came from Ayer's. Some may wonder why not a computer printout from the National Agricultural Library? Had that approach been followed it might not have been determined that a surprising percentage of journals are not received by the NAL. Of 11 journals chosen for review, two were not in the library. This comes to a rather high percentage. Selectivity, however, is a fine and useful characteristic of a librarian and is not criticized here.

A full and thorough report on the subject of agricultural journalism and the diffusion of scientific knowledge would require at least two year's research and possibly a year of organizing and writing. This project was allowed the all too brief time span of eight months. So, research had to take the form of sampling a few issues of a few journals. All of this was arbitrary but better done than left undone.

The journals considered were:

Guernsey Breeders' Journal. Peterborough, New Hampshire, volumes 81, 96, 120.

The Cattleman. Fort Worth, Texas, volumes 48 (1961-62), 56, (1969-70), 67 (1980).

National Wool Grower. Salt Lake City, Utah, volumes 50 (1960), 65 (1975), and 70 (1980).

Hoard's Dairyman. Fort Atkinson, Wisconsin, volumes 115 (1970), 121 (1976), and 124 (1979).

Arizona Farmer-Ranchman. Phoenix, Arizona, volumes 47 (1968), 52 (1973), and 56 (1977).

Progressive Farmer for Florida. Birmingham, Alabama, volume 95 (1980).

Progressive Farmer for Alabama. Birmingham, Alabama, volume 89 (1974).

Progressive Farmer for Arkansas. Birmingham, Alabama, volume 92 (1977).

Organic Gardening and Farming. Emmaus, Pennsylvania, volumes 21 (1974) and 23 (1976).

Organic Gardening. Emmaus, Pennsylvania, volume 27 (1980).

The original list of proposed journals included the American Bee Journal and the Poultry Times, both received by the NAL. Since time was running short and there was already plenty of information, those two were skipped. Briefly, the personalities of these journals are as follows:

Guernsey Breeders' Journal, over a century old, is of special interest, of course, but it is still a stern upholder of excellence in breeding and in dairying. Its circulation in 1980 totalled 4,392. Although small in size, it has outlived a vast array of once more popular journals.

The Cattleman, founded in 1914, continues to carry huge amounts of scientific and technical articles, plainly written and germane to the interests of ranchers and stockmen. Throughout its life, the Cattleman has carried on a series of somewhat quixotic quarrels with Argentina, Mexico, and the Federal Government. There is no indication that any of the four disputants is ready to surrender. Circulation in 1980 came to 23,031.

National Wool Grower, apparently founded around 1910, carries information on diseases, cures and prevention, poisonous plants, general science, and the deplorable activities of the Federal Government. The journal particularly despises coyotes. In a spirit of scientific generosity it carried one article on an experiment to teach coyotes not to like lamb. It had a circulation in 1980 of about 20,000.[6]

Hoard's Dairyman. By any accounting this is the oldest agricultural journal in continued existence in the United States. It was and is grumpy, truculent, and clearly written. Whatever the topic it addresses, Hoard's has a position and is not going to be nice about it. Since it has survived so long, with a 1980 circulation of 214,235, one is tempted to suppose that all dairymen must be grumpy and truculent. In fact, however, Hoard's also

did and does devote more space to scientific and technological matters than almost any other journal. Its wide coverage and utility must explain, in part, its continuing success.

Arizona's Farmer-Ranchman, of various lineages, seems not only to have, but probably always has had, a lively sense of humor. Even its most serious pieces are usually written with a bit of refreshing wit. In addition to its political and economic concerns, the journal carries a large amount of scientific material and, in 1980, had a circulation of 4,167.

The Progressive Farmer, founded well after Reconstruction, helped in the revitalization of Southern agriculture. At some point, well before this narrative, the journal began publishing issues for the several states which it served. Strong on science and technology, its range of interest was greater than that of any other journal surveyed. Citrus root stocks, boll weevil eradication, timber insects, fertilizers, cotton varieties, and almost anything else is covered one way or another in the Progressive Farmer. It is fairly relaxed without being actually laid-back. It becomes unrelaxed when discussing the Environmental Protection Agency which the Progressive Farmer views with distaste.

Organic Gardening and Farming was the youngest of the journals, being only 27 in 1980. Sometime between 1976 and 1980 the journal dropped the word "farming" from its title. From the beginning the journal has crusaded for organic farming and, with a sworn circulation of 1,274,518, was the most circulated journal in the sample list. Editorially, it preached to the novice and the saved. More importantly, it carried a vast array of solid scientific information often passed over by the other journals.

Taking the journals altogether, their one conspicuous characteristic was a refusal to trivialize their scientific reporting. They made no concessions to their readers and presented highly technical information with unpronounceable words without doing any appreciable violence to the scientific or technical accuracy of the report. Of course, without the benefit of a detailed market survey, it is nearly impossible to say why subscribers took any particular journals. Still, it seems that the readers were highly literate and took their science straight. Otherwise, it seems unlikely that editors, like those on the staff of the National Wool Grower, would bother with two full pages of summaries of USDA research, embracing radial tractor tires, phenothiazin drenches, vibrionic abortion, and the baneful effects of red clover when eaten by pregnant ewes.[7]

With a pile of at least 500 notes, the temptation to give endless examples is almost irresistible. To summarize the notes, the scientific and technical articles were invariably written in understandable English. Sometimes the scientific researcher seems to have been responsible, as when Dr. James Forgason reported at the "Symposium on Fertility of Beef Cattle" at the Wortham Research Laboratory, Cypress, Texas. His paper was quite

scientific and scholarly yet simply put. As Bergen and Cornelia Evans pointed out in their Dictionary of Contemporary American English Usage, scientists can write intelligibly and should. They give two informative examples.

For example, Max Born writes: "The state of a mechanical system can be represented by a point in the 6N-dimensional phase space, p, q, and its motion by a single orbit on a 'surface' of constant energy in space." If the reader has had no training in physics he will see at once that he cannot understand this sentence. He has no idea of what a 6N-dimensional space is and will not attempt to guess what aspect of it might imaginatively be called a "surface." He can see, however, that this is straightforward English and has no reason to doubt that something has been said in the simplest way possible.

The situation is quite different in sentences such as the following: "Because of the complexity of the constellation of eye conditions which contribute to blindness or severe visual incapacity, it became essential for us in formulating our program to examine the various sight-threatening conditions in terms of their amenability to control." Here the reader finds no unfamiliar concepts. He understands thoroughly what is being said and sees that it is pathetically simple. He sees that the only unfamiliar or difficult thing about the statement is its vocabulary and sentence structure, and he quite rightly resents having been put to so much trouble for so little gain.[8]

The journalists corrected any such annoyances.

By no means all of the information originated with the Department of Agriculture. The Arizona Farmer-Ranchman carried a report from the U.S. Geological Survey in 1968. Something about the report suggests some journalists improved on its literary value, at least at the outset:

> Electronic science is being employed more, and more effectively in analyzing what's happening to Arizona groundwater and what can be expected in the future at different rates of withdrawal.

Thereafter the report becomes slightly murky, but good enough.[9]

How much of all of this sunk in? Well, it's hard to say but there are a few indications. Letters to the editor show reader response and Hoard's Dairyman and Organic Gardening carried these in great volume. The letters were selected primarily for their queries about science and technology. Then there were the advertisements. One can usually count on the cash nexus, at least over time. One would suppose that a Ladybug breeder who sold Ladybugs by the pint would not long continue to advertise if no one paid any attention to his contribution to biological control of insects.[10]

Letters to the editor were a feature of Hoard's even in the 19th century. Aside from Organic Gardening, the National Wool Grower and the Guernsey Breeders' Journal were the only other journals to carry letters to the editor. The last two did not carry them in very large volume. Now and then, scientists or other knowledgeable people wrote in to correct the journal or one another. Sometimes the exchanges verged on acrimony, and at other times took the form of quite gentle corrections.[11]

Now for the advertisements. Almost all the advertisements which appeared in the agricultural journals appeared nowhere else it seems. Of course, the non-agricultural research was conducted in barbershops and waiting rooms of one sort or another. Still, the non-agricultural selection was wide enough to offer the tentative observation that an advertisement for the Troy Bilt garden tiller would only appear in agricultural journals.[12]

The ads did not always, nor even often, present new scientific information but, rather, disseminated fairly well established applied science. The agricultural usefulness of earthworms had long been known, for example, but the development of large scale and widespread earthworm raising was something new. Very recently the California legislature considered, and may even have passed, a law declaring earthworm husbandry to be a form of agriculture. The idea was to classify this kind of animal husbandry in such a way that the California Department of Agriculture could regulate the industry. What could be more natural then than to find an advertisement urging:

> Let Nature Do Your Gardening
>
> The amazing Red Hybrid Earthworms
>
> - build top soil
> - turn garden debris into rich compost
> - speed nutrients to roots without chemicals or poisons.[13]

Above all, the advertisements constantly drew farmers' attention to new aspects of applied science, from fertilizers with micronutrients, to nematicides, to post-emergent herbicides. And, as the saying has it, and more, much more. The reader, alerted to the product, could easily enough get from experiment stations, the Extension Service, and other places information on the value and safety of the product. Sophisticated readers, which almost all farmers are, could easily discount exaggerated claims. The important thing was to know that a class of seed, chemical, animal, or machine was on the market.[14]

About the mid-1970's electronics began to make an impact on American farming. At first the science and technology merely took the form of agricultural application of non-agricultural advances. For example, there

was the C.B. Walkie-talkie to keep the farmer in touch with his headquarters, or the other way around.

Then in 1980, three different companies offered electronic devices to test ewes for pregnancy. It seems unfair to quote one without the others but, in general, the device was placed on the ewe's side and it then signaled if she was pregnant or not. One advertiser succinctly explained the point to it all: "You can't afford to waste time, feed and facilities on open ewes." The journal may have carried an article on the device but, if not, no matter. The manufacturers informed their public.[15] At least one of the advertisements boasted that the pregnancy detector could scan 200 sheep an hour. As usual, science and technology were not on the side of the small producer.

Scientists, technicians, engineers, and all sorts of support people generally work on rather discreet problems. For the most part, they all seem to know that their work is just a part of the whole and, judging from their printed reports, know what the whole is. All discoveries and devices are so inter-related, and are so close to the present, that it is impossible to say for certain what the great scientific achievements were. They seem to have taken place chiefly in genetics and biochemistry. These subjects made up the vast majority of the material printed by the agricultural journalists.[16]

Agricultural journals of any sort serve as vehicles for the transmission of scientific and technological information. They always give the source of their information so that any reader may get the technical publication where the information first appeared. Unlike the elusive electronic media, the journals made a permanent record of what had been done and what was to come.

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16. Proof of these assertions would be difficult and, if done, the results would be too tedious to read.

THE ROLE OF RADIO AND TELEVISION IN COMMUNICATING AGRICULTURAL SCIENTIFIC KNOWLEDGE

by

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As this presentation has as its theme the effects of broadcasting on the communication of agricultural knowledge, we shall not dwell to extreme on the chronology of the development of this twentieth century conduit of information. We will point out, however, that radio came along just in time to give a tremendous and significant boost to the agricultural explosion on American farms that began earlier with such innovations as the mold board plow, the mechanical harvester, the use of chemicals, the advent of the land-grant universities, and the agricultural extension services. It should also be mentioned that the very word "broadcasting" has agricultural origins, referring to the way seed was sown in the olden days--not "narrow casting" as in row planting and nowadays on electronic cables.

There seems to be little doubt that the broadcasting of scientific information for agriculture took place on a sustained basis first in the United States followed to some degree soon by other English speaking countries. It would also be fair to recognize that the day-to-day broadcasting of such information runs more to the applied kind of science than to the basic, though there is much of that, too. News of hybrid corn developments, high lysine corn, multiplied yields of nearly everything including things like the twinning of lambs, rates of livestock and poultry gain per pound of feed, the use of chemicals, especially the new ones, are all pretty close to basic research.

At first, farmers, being human, liked the new fangled window on the world not so much for the farming information that it brought but for the entertainment, the release from isolation and boredom enforced through the ages by distance, muddy roads, poor telephone service or none at all, newspapers that came several days late with market reports of the same vintage. Weather forecasting was an important item in the beginning, especially to farmers who then had to use often unreliable battery operated receivers until the Rural Electrification Administration started to wire up rural America in the mid-thirties.

Isaac Asimov, the famed science writer, has said that it is possible for a civilization to arise without learning to write, and mentioned the Incas of Peru as an example. He acknowledges, however, the importance of writing which he called the "second revolution." The first of these revolutions was speech, the third was printing, and the fourth was the great explosion of broadcasting with all its possibilities still developing involving satellites, fiber optics, home computers, teletext, and all the rest.

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Asimov, as do others, looks forward to the time when every person will have his own electric outlet as every one now can have his own library. He said this a decade ago and we are now approaching the time when the technique and hardware for that exist, even though the economics is not yet feasible.

The people who operated broadcasting stations in the early 1920's did it on an experimental level, as did the listeners who had receivers. At a hearing of the Federal Communications Commission, J. Clyde Marquis, director of information for the Bureau of Agricultural Economics at the U.S. Department of Agriculture in the 1920's, testified as follows:

> The development of the distribution of market reports by radio broadcasting began in December 1920 with experimental broadcasts from the station of the U.S. Bureau of Standards in Washington. Those first ones were by radio telephone. This was one of the first practical uses of wireless communication particularly by farmers, being preceded by the broadcasting of weather reports and provided the missing link in the distribution of information to farmers making it possible for them to receive news as promptly as traders and others in the market center.

How the USDA got into this so early was something of a coincidence. Things do depend a lot on being at the right place at the right time. The officer in charge of distribution of market reports in the USDA was greatly interested in the development of radio because his son was an amateur operator. This put him in contact with the early experiments in broadcasting at the Federal Bureau of Standards. That officer, William A. Wheeler, prepared the material which was first used by the Bureau of Standards and other stations.

Even in those innocent times, the USDA had an extensive market news system with branch offices in about 20 cities connected by a leased wire making national market news available at those points. These offices started sending the market news to local broadcasters who at first were mainly amateur radio operators who recorded the information (by pencil, I think) and delivered the copies to local farmers, bankers, county agents, and others for further dissemination. People who owned telephones helped out, with their party line connections, no doubt.

By 1932 there were 150 stations using regular market news broadcasts and a total of 253 using some sort of information. The Agricultural Marketing Service has expanded the service since then, of course, and is not able now to count the stations using market information. It would run into the thousands. The people issuing the information in that early day found that a number of short flashes of various periods during the day were needed to make the service of greatest value to the listeners rather than a longer time period with much detail late in the day or in the evening.

Mr. Marquis went on to state that the Department, through its news service, supplemented broadcasting in the early stages by spreading information through the agricultural extension service, the farm press, and other agencies advising farmers by radio as to what was available. This was considered so important that the USDA, in cooperation with the Bureau of Standards, prepared and distributed descriptive circulars on the construction of inexpensive crystal receiving sets to be built by farm children associated with the Extension Service.

Thousands of these crystal sets were made and the use of broadcasts was greatly extended as a result of this information during the period preceding introduction of the less expensive standard sets and the advent of rural electrification. The transistor set was still a generation away.

The Department of Agriculture was so pleased by this new avenue of information that, in December of 1924, an Agricultural Radio Conference was held in Chicago by the Director of Extension, Mr. C. E. Warburton, with the blessing of the Secretary of Agriculture, Mr. Henry C. Wallace. This conference was attended by representatives of state departments of agriculture, agricultural colleges, national farm organizations, the farm press, managers of radio stations, representatives of trade associations and from the various branches of the USDA. Resolutions were adopted urging that agricultural radio broadcasts be extended as rapidly as evidence of the matter justified and as reliable facilities permitted. Morse Salisbury, the chief of the Radio Service in 1932, testified at that same hearing of the FCC that the USDA Press Service had started a semi-weekly news service to broadcasting stations in 1925 and that, at the beginning of 1926, the Radio Service was set up as a unit of the newly organized Office of Information.

Early in 1920 the number of rural radio sets in the United States reached nearly one million. The Radio Service was established to propagate programs and to adapt timely subject matter for radio presentation. Ninety broadcasting stations representing every section of the country lent their facilities to the USDA for an average of half an hour daily, Salisbury told the hearing. I would not want to dispute that gentleman, who did so much to enhance the USDA Radio Service, but that amount of time daily by that many stations seems improbable even for that era when stations often had to scrape for material. Mr. Salisbury could have been impressive with half that number. Nowadays, of course, we have several hundred stations doing more farm programming than that but they don't just turn things over to the USDA. And that is as it should be.

The Department's radio scripts were at first digests of the most timely pertinent facts woven into story form and covering a wide range of topics. The fall and winter script schedule of the Radio Service included 20 special program features each week. The United States Radio Farm School, which had already brought requests for half a million enrollment cards, was conducted from 25 stations. Lessons took the form of experience talks and imaginary inspection tours. Radio "schoolmasters" at the different stations conducted the classes. Material was dramatized so as to catch and hold the interest of the listeners. Printed lessons were mailed to all enrollees.

Another outstanding service, released from 50 stations, was called "noonday flashes." That enabled a million farmers to listen in daily on a conversation between a county agent and a farmer discussing current problems. "Aunt Sammy," a new radio friend and neighbor for the five million farm women in the nation, heard from 40 stations in 1932, actually grew to many more and endured for many years. "Aunt Sammy," presumably the wife of Uncle Sam, issued a cookbook which, apparently, was reviewed and updated just a few years ago to meet current nutritional standards.

There was another service for the girls known as "Housekeepers' Chats," a 15-minute period devoted five days a week exclusively to the up-to-date information subjects of interest to women. Some of the other special programs of those years had titles like "A Weekly Letter to Dad" in which a son at college writes home telling about his studies in agriculture, "Autobiographies of Infamous Bugs and Rodents," "Pests That Bother Now"--told by the insects and rodents themselves--"Chats by the Weatherman," "A Primer for Town Farmers," "An Interview with an Agricultural Economist," and "Weekly Farm Digest." In those days the Radio Service had three busy writers who enjoyed the cooperation of USDA scientists and others in varying degrees to keep the information flowing.

In 1929 Milton Eisenhower, then Director of USDA Office of Information, reported to Secretary Arthur H. Hyde that the National Broadcasting Company had put a network of 17 stations at the disposal of the USDA to carry a 15-minute broadcast each weekday at 1:15. Eisenhower went on to state that plans were set up with NBC for a National Farm and Home Hour with 37 stations and the air time to be extended to 45 minutes. Most records show, however, that the National Farm and Home Hour was started in 1928, a joint presentation of NBC and the USDA, with the program originating in Chicago and Washington.

The National Farm and Home Hour ran until 1945 as a daily broadcast, six days per week. Off the air for a few months it came back later that year once-a-week on Saturday for a full hour, sponsored by the Allis-Chalmers Company with participation by the USDA. That took some soul-searching at the USDA, to decide to get in bed with a commercial sponsor, but agreements were worked out so that the USDA would not be put into a position of endorsement and the arrangement went very well. Both Allis-Chalmers, the advertising agency, and the network were most responsive to the USDA's wishes in such matters. This arrangement continued until 1960 at which time both the sponsor and the network were eager to get out. The agency tried in vain to find other sponsors and to revive the program. The USDA did not put up a big objection, recognizing the changing pattern of broadcasting.

NBC then offered the USDA certain regular spots on its ongoing "Weekday" and weekend "Monitor" programs which the USDA accepted and these ran for a year to two. But the National Farm and Home Hour was a popular one with its fine

music from Chicago, with its master of ceremonies, Everett Mitchell, with his hearty "It's a bee-ootiful day in Chicago" even though the weather there was often unspeakable in winter. And, of course, there were the headlines and occasional interviews from Washington. For example, Secretary of Agriculture Henry A. Wallace made many of the announcements concerning agricultural action programs. Research reports were standard fare, too, and scientists were regular participants. Many scientists at first were reluctant but the results that an appearance on the network brought soon overcame such reticence. There were remote pickups, too, from fairs, livestock shows, land-grant universities, laboratories, 4-H Club events, and now and then a feature from abroad.

Not many years after NBC started the National Farm and Home Hour in 1928, the American Broadcasting Company, which had been the old NBC Blue Network, started its own American Farmer program. This actually came after the Allis-Chalmers sponsorship of the Farm and Home Hour on NBC in 1945 but that program was never able to attract a commercial sponsor. The Columbia Broadcasting System launched its Saturday Columbia Country Journal in the late thirties. It persisted until the mid-fifties but never attained the audience that the Farm and Home Hour enjoyed. One memorable Saturday about 1948 all three of the network farm programs originated live from Forth Worth during the big annual stock show there. All three networks sent their men down, NBC sending two or three. As farm editor of WBAP there at the time, I was on live on NBC and ABC, one from the studios and the other form the show ring.

In 1954 the Clear Channel Broadcasting Service with 18 50 kilowatt stations active in that group launched a weekly program called "Agriculture USA." It was a quarter hour program most of the time and Hollis Seavey, the Director of the CCBS, produced the show in the USDA studios, at other times on Capitol Hill. Later the CCBS pulled out and the USDA took it over. That program is still on the air to about 300 stations now.

As to the effectiveness of farm broadcasting, USDA officials went on record back in the thirties with some of the success stories of the New Deal farm programs. During the Cotton Signup Campaign in 1933, Dan T. Gray, Dean of Agriculture at the University of Arkansas, made a field trip around the cotton areas and found that radio had been the principal source of information for many of the tenants. He reported that numbers of the land owners were puzzled over their tenants' profound understanding of the cotton program until they realized that the radios on the plantations and in the communities, stores, garages, and so forth were the noon day daily centers of interest when the Arkansas Cotton Campaign News Digest went on the air from seven stations in the state.

Nowadays, this kind of news would be handled by farm broadcasters working for the stations or by special spots sent to the stations from Washington or the state university and inserted into farm or news programs. There would also be interviews with local and national officials detailing the program for easy understanding by all levels of farmers. In Tennessee, Extension Editor, A. G. Sims, told how he had to do some tall talking to persuade County Agent Murphy to try a daily radio program even experimentally in Knoxville. After 18 months, however, Murphy was emphatic in saying that the radio program was about the last thing he would want to give up.

In the mid-thirties stations came to discover that money could be made in broadcasting. The networks began to extend across the land--first NBC then CBS and NBC Blue and Mutual and some regional networks. Competition for air time became more intense. Stations were no longer as eager to fill up their broadcasting time with agricultural and homemaking programs which brought in no revenue with which to pay salaries, the electric bill, and bonuses for the boss and prized talent.

It might well be considered then that the most effective stimulus for farm broadcasting came from the Federal Communications Act of 1934. This was strengthened, in the early forties, by the celebrated Blue Book issued by the FCC regarding public service responsibilities of broadcasters. It propelled many stations into farm broadcasting who had dropped it or had never thought about starting, especially since it was acceptable now for farm programs to have commercial sponsorship. Stations found that there was gold to be had.

Some radio stations had become involved in the act early, hiring people to do farm programs exclusively. The land-grant institutions that operated stations made good use of them. Some stations achieved great fame for their programs aimed at rural people. WLS Chicago, for example, which owner Sears Roebuck had named for "World's Largest Store" before selling it to the Prairie Farmer Magazine, did this. KDKA, the Westinghouse station in Pittsburgh sent its farm man to NBC where he started the National Farm and Home Hour and later became executive vice-president of the network, Frank Mullen.

The U.S. Department of Agriculture was not sitting idly by, however, and virtually every land-grant college and university in the country started up some form of similar broadcasting services, some more elaborate than others to be sure. The Federal Extension Service sent trainers out to help state and county extension personnel learn the techniques of broadcasting on radio and to relate to station management and other aspects of this exploding new medium. Some of the agents took to it like cats take to goldfish. Others went along kicking and screaming. Some of the programs that they did are memorable, especially some of those by the people who wished it would go away.

In the begining the USDA didn't want its people or its material used on sponsored programs, but it soon got over that. An understanding was reached with station leadership that none of the material from the USDA would be used to imply endorsement of a product or a service or a point of view. USDA employees would not do commercials or conduct programs on which commercials were presented but could appear as guests on such programs, performing in their roles as USDA representatives talking about their assigned official duties.

It was during World War II that the farm broadcasters formed their professional society and this got a boost from the USDA. Wallace Radderly, the Chief of the Radio Service at that time, wanted to get more information out about food production, rationing of supplies, and such. He contacted some of the best known farm broadcasters, especially Larry Haeg of WCCO Minneapolis and, as a result, the National Association of Farm Broadcasters with both radio and television members. Active members number about 250, associate members more than that.

Land-grant institutions fed radio and television programs to their states in various forms. Trade associations and agricultural organizations fed radio tapes and telephoned so-called news to stations regularly. Some of these latter represent a point of view on such current issues as agricultural legislation, environmental regulations, the use of chemicals, agricultural exports, puff pieces for the organizations themselves or their leaders. Some deal with scientific breakthroughs, especially those stories coming from chemical laboratories. The land-grant institutions deal with a wide range of topics from basic research finds to recommended practices and news of seminars.

I think it is true that day in and day out, considering how much they are on the air, the broadcasters feed more agricultural information to farmers and farm-minded people generally than any other medium; not only that, more of their information comes originally from the U.S. Department of Agriculture in one way or another than from any other single source.

In all of the surveys that I have had anything to do with asking which subjects farm broadcasters were more interested in, research always comes out ahead. New ways of doing things for economy of time and profit, new chemicals, new varieties, and new scientific developments have a certain magic. I know of no one who argues that a broadcast can be as thorough, as probing, as detailed as a printed piece which can be available for review and can go on for thousands of words, something that is rarely available for broadcast now, though there are signs that it may be common in the future.

It is hard to beat a broadcast program for its value in creating an awareness of new ideas, methods, and conditions. This leads to further knowledge-seeking in the journals, the experiment stations, the seminars, the books, and the graduate school classes.

Syndication and networking of farm programs were never successful after the big nets got out of the business until the past 10 years when regional nets of radio stations bought programs provided from a central supplier. Most of these have been targeted to single states or single farming regions. There are now some 20 of these regional nets in operation serving from three to up to 150 stations with markets, weather, farm news, interviews, and the like several times per day, every day, except Sunday.

Television farm networking has not gone that far. Aside from the USDA programs, there is one "U.S. Farm Report" which is produced and distributed by WGN Chicago and sponsored by International Harvester and goes to about 80 stations once a week on tape. For a couple of years now a program called "Country Day" is transmitted from KSTP Minneapolis by wire to about 50 stations in the midwest. The newest effort along that line is "Agriculture Day," a daily half-hour program fed by satellite from Terre Haute, Indiana (later to move to Indianapolis) to some 50 stations. All earlier attempts at a sustained television network farm program have failed but new hardware and new conditions may be favorable for this vast potential.

In the early fifties the Chief of the Radio and Television Service of the USDA felt that television was too expensive, too time consuming, and too much of an undertaking for USDA. He had a solid basis for this belief. There was neither money nor facilities and only a small staff for launching a television program. In fact, there never has been any money in that office, at least in modern times, for starting up any service. The money, if any, comes after the service has been started on a shoestring and a few crumbs. Despite all that, a study was made with some funds provided by the Agricultural Marketing Service. An experiment was run with black and white blown-up printed still photos and scripts distributed to stations telling stories of agricultural research. This was before color television was available. In due course, when most stations were into color, we had to shift from the black and white photos to colored transparencies, but it was still a fairly pedestrian service. We were amazed, however, at the demand.

In the meantime, the Agricultural Research Service was having the Motion Picture Service of USDA make an occasional feature on film which the ARS named "Beltsville Newsreel." It featured research findings, as one might imagine. This, too, was popular with television stations.

During the early fifties NBC (and other networks) were experimenting with color and the USDA was cooperating with the Washington NBC TV station in some experimental broadcasts to determine how things like fruit, meat, vegetables, and so forth would look on camera as well as how different colors came through and how they acted when close together.

This came about because of the long association that the USDA had with NBC in the National Farm and Home Hour, and it eventually led to a weekly program on the Washington NBC TV stations produced by the Department

in cooperation with the station. All expenses were paid by the latter. This arrangement continued for almost 20 years and if you know something about the cost of equipment, TV time on the air, tape, and union wages for crews, you'll recognize that it adds up to a sizeable contribution to public service, not to mention the added serendipity of USDA sending those tapes around the country for use on other stations, up to about 100 at one time.

As though that wasn't enough, the NBC station (WRC-TV) came up with an idea for a daily show which was handled in much the same way. It fits into a five-minute slot and the Public Service Director at WRC-TV named it "Down to Earth," and it has been running on stations all over the country since about 1962. I never liked the name very much but you can't argue with success, or you shouldn't. By the way, the USDA is now starting to produce that program with its own equipment, something we would not have been able to do 20 years ago. But we were not, however, a glamour agency like the military services, the space agency, the atomic energy crowd and some others, so we couldn't afford the equipment until it has become smaller, less complex, and less expensive.

The USDA also does quite a bit to place its people on network programs and local stations as they travel around keeping their speaking engagements, inpsecting experiment stations, attending conferences, and the like. The local stations are usually glad to have them, especially the farm programmers. One early Agricultural Research Service information man, Frank Teuton, organized what was called Frank's "Medicine Show," with USDA girls modeling clothes made from agricultural products. Later, Dr. Mark Cathey, now director of the National Arboretum, but then a horticulturist at Beltsville specializing in ornamental plants, was so popular on television that he did a series of guest appearance on NBC's TODAY program.

How much all this broadcasting has contributed to increased production of food or more efficient marketing of agricultural products it is hard to prove. Everyone knows that broadcasting by its pervasiveness, its immediacy, its ability to reach people who don't ready very much, is powerful.

We have asked for reports on this and what we generally get is statistics on yield increases which have happened concurrent to broadcast programs. Officials tell us, yes, the broadcasts have been of great value. But I don't think that even they could prove it statistically. We know that yields have improved in many areas of the world where broadcasting has played an important role, perhaps in combination with visual aids of various kinds, printed bulletins, demonstration projects, and the rest.

Farm broadcasting in other countries is rarely like that in the United States. For one thing, there is less sponsored programming abroad. The government is more likely to be in the act in other countries, and many make use of the

so-called "soap opera" technique to trap the listener into hearing something useful that one only listens to because it is entertaining. "Education by stealth" is what one British broadcaster called this technique.

Canada got into farm programming via the Canadian Broadcasting Corporation, the quasi-government operated network. Australia got going right after World War II, serving its far-flung "stations" (ranches, not broadcasting stations) across the outback as well as those near the coastlines. The United Kingdom with its BBC started carrying farm programs early and even provided battery-operated radio receivers to rural people in some of its African colonies. They were called "sauce pan" radios because they were round, metal, and nearly indestructible.

By 1951 there was enough interest in farm broadcasting in Western Europe for the U.S. Aid program to promote a conference at the BBC in London. Several of us trainers around Europe at that time started promoting farm broadcasting with rather good results. In 1954 we held a farm radio seminar in Italy attended by 11 countries all of them doing farm radio broadcasting of one kind or another.

Several countries have copied the BBC with its quasi soap opera farm program called "The Archers" which started in 1951 and is still running. It was set up originally in cooperation with the British Ministry of Agriculture, Food and Fisheries to dispense timely information about farming with the Ministry as the main source. The program is still popular, though it has its problems, and no longer has any strong connection with the Ministry. I am told that the Queen Mum, Mary, listens to it, though I doubt that Lady Diana does.

The CBC in Canada had a similar series running but cancelled it after a few years. Nothing like that has ever been tried in the United States, but some other countries, like Spain and Yugoslavia that I know of, have had a comic series running with the purpose of conveying agricultural information.

The Canadian Department of Agriculture, through the CBC, had the National Farm Radio Forums going in the late forties with regular rapping hours, group listening, and study guides. The United National Education, Scientific, and Cultural Organization made a study of its effectiveness and issued a comprehensive report which is available in libraries. It gives a good grade to the Radio Farm Forums as a disseminator of information to farmers. That technique has been copied in several countries--India for one--and they are still running there. I attended one in a village one night. There are voluminous reports available on who has participated in these radio farm forums in India, Africa, and quite a few other places. The idea of the discussion period following broadcasts, with study guides and competent leaders, seems to have proved itself especially in places where village isolation is a factor. In India, where villages may be only a mile apart, there is still isolation insofar as communication is concerned. Radio is the medium, more effective than print in many instances. While television is good, it is expensive and not universal enough yet. Along the

way, the Food and Agriculture Organization of the United Nations got into the farm radio act, though it may well be said that it was dragged in by the foot.

Here I give my old Australian friend, John Douglas, a lot of credit. He had started the Australian Broadcasting Commission's Rural Service right after World War II, pretty much by bulldozing the bureaucrats in Australia to do it. And John could be a formidable promoter sometimes. After about 20 years of that he did pretty much the same thing with the FAO in Rome, as a special consultant, after he had attracted the attention of the FAO Director, General B. R. Sen, when the latter was on an official visit to Australia.

Douglas went to the FAO for a year, but stayed for five. Almost single handedly he promoted workshops in several countries on farm radio. The FAO had no money it was willing to commit for such enterprises at first, so Douglas personally raised some funds, back home in Australia, from the Oxfam Group in Britain, and from the UN Stamp Fund to finance one seminar in Cairo, serving about a dozen countries. That was such a success that the FAO then found some funds. One should not overlook similar work that has been done by the Rockefeller, Ford, and other foundations in developing countries, and by the work with rural people through its broadcasts.

While all this was going on the United States aid programs continued around the world. Wallace Kadderly worked in Central America on agricultural information techniques, after leaving Europe. Later he worked in Japan for a couple of years. Wallace had been a farm broadcaster, so he gave much emphasis to that in his work abroad. The Japanese now have extensive broadcast facilities, as nearly everyone knows. One of their programs is "Bright Little Farm." I would say that program would not be very similar to one coming from Omaha, Nebraska. We visited Radio Moscow in 1974 and were shown how radio programs are piped into the 11 time zones served by that system. It seemed pretty superficial to us, we decided, the program dealing mostly with statistics, awards to quota winning producers, pictures of giant farm machines running and so on.

We've heard much about the Green Revolution. I suppose the jury is still out on that, but in every place we've heard about--in Mexico, in the Philippines, in Pakistan, etc.--there are farm radio programs going in one form or another, playing some role in the promotion of better food production.

SCIENCE AND SOCIETY

by

ROBERT L. CLODIUS

Wisdom profound enough to be carved into granite often has a way of losing its impact through familiarity. I am thinking particularly of the words chiseled into the entrance of the National Archives here in Washington: "The Past is Prologue." A bit of profound wisdom -- accepted, passed on to generations, carved into the housing of our heritage for all to see. But how seldom is its truth applied to comtemporary problems.

Because you represent a national library and its associates, as well as a history society, I thought this theme--the past is prologue--would be an appropriate concept to employ in seeking some truthful observations about our subject at hand: science and society in the latter part of the 20th century. The "Past" upon which I wish to elaborate is less that of the historian and scholar than the biographer--the autobiographer, to be precise. I want to tell a personal story--one man's view of the past and its meaning. In doing so, however, I recall other words of wisdom that tell us "all history is biography."

Here, then, is my history, in the form of four "radicalizing events" that have shaped my thinking and the quality and content of my life. They may, on inspection, be universals for my generation: bringing us to this point in time, and showing us something of the future--its promise and its peril. The first radicalizing event in my life was, of course, the Great Depression. Triggered by the stock market crash of 1929, that shattering event had repercussions for the nation that extended through the next decade, and through what was the first great experiment in demand-side economics: the Keynesian Revolution. From this I learned that the best security comes from developing one's self as fully and completely as possible.

The second radicalizing event was World War II. I didn't start it, and I didn't end it, but for those of my generation who were in it and for millions of others, our heads and our lives would never again be the same. The war and its aftermath set in motion the external circumstances which would have a profound effect on us all by changing the fundamental nature of our society.

The Civil Rights movement, with its emphasis on human dignity and the basic shared right of all people as human beings, had its apex perhaps in the anti-war movement of the Vietnam era. This period, collectively, was the third great radicalizing event of my life, and it was traumatic not only from a purely personal standpoint, but also from the perspective of my being a university official charged with the care and instruction of the next generation. As the executive vice-president of the University of Wisconsin at that time, I had the

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dubious distinction of being Wisconsin's first university administrator seized and held hostage by his own students. One comes out of such an experience a different person, unable to think the same ways about some matters. During this period, I also suffered threats of physical violence--against my family, my children, my household, all of the things that I held true, near, and dear. But the experience bolstered, rather than diminished, my belief in the strength of our democratic values and institutions.

The fourth of my radicalizing events was purely personal. I spent six years of my life in Indonesia during the 1970's, an experience that taught me much about other cultures, other languages, other faiths (particularly Islam), and the concept of the extended family, within which my wife and I acquired three Indonesian nephews and a niece. I also learned, through this experience, that there are other logics governing thought and behavior in the world than that of the Western tradition. Believe me, our logic isn't necessarily logical when cast in the context of another culture.

I would like to propose to you today that we may, at this very time, be embarked upon the course of history which will ultimately become the fifth radicalizing event of my lifetime. Something happened to the basic structure of our society in the economic aftermath of the Vietnam war, with its inflationary perils sharply exacerbated in the energy crisis. It was something that is now working itself out in the first great experiment of supply-side economics. We are the subjects of that experiment and, unlike human subjects protected by the federal government in the laboratory, we were never asked whether we wanted to be part of such a grand experiment. An obvious disaster accruing from this experiment is the unemployment and the lost production of 11 million Americans. We will all be changed by this experiment, along with our society.

One aspect of this societal change will be a heightening of America's dependence on its system of education--and this is the fundamental truth that links all of my life's radicalizing events. Learning, problem-solving, inventiveness, adaptability, depth of understanding--these are the basics that have provided the nation, time and again, with the wherewithall to persevere and to master. Today's challenge is broadly economic, but it reaches, as the other events did, all the way into the spiritual and moral substance of the nation. Basically, this economic crisis shows more clearly perhaps than any other historical moment to date how interdependent the so-called American way of life is on the American approach to education. Put another way, I hope to show that economics and education cannot be isolated from one another or from the way we live--the quality and substance of our lives.

Since the oil embargo of 1973, Americans have turned with new urgency to the examination of an age-old dilemma: resource scarcity. For much of our 200 years as a nation, the question of self-sufficiency had been a moot one. The western movement of the American frontier disclosed not only the rich agricultural lands of the prairie but also the vast extent of the nation's natural endowment of minerals, timberland, waterways, and game. Frontierism also engendered within the American spirit the human resources necessary to transform this natural endowment into industrial preeminence. America became a nation of innovators -- creators of electric lighting, telephone communications, automation, turbine engines, assembly-line manufacturing, atomic power plants, and much more.

For a time, our relative isolation from the conflicts of Europe enhanced this sense of self-sufficiency. We were, in fact as well as in evolving myth, the new land of opportunity, exempted, or so it seemed, from history's prime motivation for war: the clash of pressing needs for space, food, and other resources vital to a nation's well-being.

The shock wave of 1973, however, altered our perception of ourselves. And from that standpoint it will probably serve the historians as a so-called water-shed event in the nation's development. Coming as it did on the heels of the tragedy of Vietnam, a decade of slippage in America's domination of the world market place, the worrisome build up of Soviet military might, and the dark soul-searching era known by the code name of Watergate, the realization of resource insufficiency -- of possible limits to the American dream of continual growth -- had a multifaceted, often contradictory effect on the national psyche. On the one hand, we began with this impetus, the positive exercise of examining our strengths and weaknesses in the context of a changing world. On the other hand, unfortunately, we assumed a pervasive, almost unconscious attitude of retreat. What many have called the Age of Limits was translated to mean an era of diminishing expectation.

The thesis of my speech is that this tendency toward retreat need not be the promise of the 21st century. To misconstrue the challenge of the 1980's as merely the need to tighten our belts, adjust to our fate, and arm ourselves with weaponry alone, would be a tragic mistake at a crucial juncture of our history. The times and our position of world leadership demand a creative and carefully charted approach to the problem of resource scarcity, one that incorporates the traditional strength of our people -- their ingenuity -- with the realities of rapid international change. I believe that such an approach must originate in the realm of science and technology, an area which, in our modern world, offers the ultimate weapon against fear, privation, sickness, want, and inertia. Science and technology alone can keep alive the promise of unlimited materialistic possiblity.

I further believe that the federal government, in charting such an approach, must be conscious of certain alarming trends that threaten our scientific capabilities, and must take immediate steps to counter these trends and to insure the continuation of a long tradition of excellence in the teaching of science, mathematics, and engineering, in the conduct of basic and applied research, and in the transfer of technology. Now let's take a closer look at the resource problem.

While the energy crisis did us the unquestioned favor of focusing our attention on the finite nature of nature itself, it may also have helped to skew our conception of resources in general, and of resource scarcity in particular. We are suffering, for example, from a shortage of oil, not of energy per se. The United States, with one-third of the world's known supply of recoverable coal, has beneath its earth today energy resources that experts say could fuel at least the next 300 years. The question thus becomes one of societal choice guided by technology: how, where, when, and in what manner to exploit these and other alternate energy resources. In this context, it may be instructive to note that, little more than 100 years ago, the world faced an equally vexing energy crisis in the dwindling supply of whales for whale oil. The solution then, as today, rested with scientific ingenuity, the capacity to (1) discover the uses of petroleum, and (2) devise the technology needed for that use.

The resource problem, then, could first be seen as one of relative scarcity--the relative scarcity of products in use. Science and technology offer the only avenues for dealing effectively with such scarcity, by enabling us (1) to find new sources of needed material and services, (2) to identify and develop resource substitutes, and (3) to increase the relative resource base through greater efficiency and innovation.

But the concept of resources and resource constraints extends beyond the energy crisis, beyond even the notion of non-renewable raw materials and their substitutes. The term "national resources" implies, in a broader sense, the sum total of a nation's capacity to supply certain essential elements of national life. This encompasses methods, means, and manpower as well as materials. The measurement of our agricultural resources, for example, includes produce and livestock as well as the aggregate system operating to insure sufficient food for the present and increasing yields for the future. That system, in turn, is an amalgam of human talent, social institutions, sophisticated machinery, detailed information, and constantly improving methodology. Similarly, health resources are measured in human as well as in scientific, technological, and operational terms. We speak of an American "health care system" that seeks to provide increasingly more comprehensive and effective resources for individuals against the threat of disease and injury.

In the multi-dimensional sphere of national security, our store of resources includes not only military hardware and personnel but also certain less tangible elements of strength and deterrence: the research capacity to match advances in weaponry by potential enemies and to deal with threats to our own internal well-being; a competitive economy, able to meet the rising expectations of our own citizens and to help meet those of other less developed countries whose friendship, trade, and resources we need; a scientifically literate and internationally aware populace, providing an adequate pool of technologically knowledgeable manpower for industry and the military, as well as sensitive world citizens capable of devising alternatives to armed conflict.

Finally, because scarcity is the controlling factor in rising prices, resource constraints in such vital areas of our national life can properly be viewed as a chief contributor to the inflationary spiral. If we are able, through the fruits of science and technology, to expand our resource base in these areas--to provide more and better energy sources, more and better health care options, more plentiful and less expensive food supplies, greater quantities of more efficient defense-related materials--prices will drop as quantity rises. By addressing the supply side of the inflationary question--by increasing the productivity of labor through innovation, while expanding the resource base--science can help provide a solid undergirding for the economic rejuvenation of America.

Bringing down inflation by squeezing the money supply and limiting people's access to credit is a Scrooge-like policy, niggardly, and mean-spirited. Bringing down inflation and stabilizing prices by producing adequate supplies of goods and services through full employment of the labor force is generous and noble.

And in all of this there is a federal role. One hallmark of the American vision has been an instinctive reach for new knowledge as a means for overcoming both internal and external limits to achievement. It is no accident that Thomas Jefferson, with his unquenchable thirst for mastery in such fields of learning as architecture, science, music, literature, and agriculture, penned the nation's Declaration of Independence. Nor was it an accident that Benjamin Franklin, whose inventive curiosity has come to be symbolized by a kite flying against a storm, was a moving force behind the U.S. Constitution. Both men championed their free exercise of the human mind and urged its encouragement through education not only as a bulwark

against tyranny but also as a key to prosperity. We need look no further than Article 1 of the Constitution to see the importance that the founding fathers placed on the fostering of inventiveness and the creation of new knowledge. In Section 8, the Congress of the United States was empowered to "promote the progress of science and the useful arts" through patent and copyright provisions.

It is a broader constitutional charge, however, that compels us this watershed decade to reaffirm our national commitment to excellence in scientific and technological endeavors: that simply stated but profoundly complex directive placing with the federal government responsibility "to provide for the common defense and to promote the general welfare." Federal support for education has evolved because of perceived national needs. A clear example of this is the land-grant act signed into law on July 2, 1862, by a beleaguered President Abraham Lincoln in the middle of the Civil War. In this landmark act of the Congress, the rising tide of Democratic idealism reached a high point. The land-grant movement's impact has brought to the United States benefits beyond measure. A recitation of these, and of the progressive implementation of the ideal implicit in the original legislation, is not necessary today.

The federal involvement in education extended through the years to support for health research, and, in the reflection of an awareness of the tangible results of scientific research, to areas of science which expanded dramatically following World War II. Still later, when the first satellite to soar in space turned out to be the Soviet Sputnik, the federal government strongly backed, through the National Defense Education Act, support for students.

Nevertheless, this tradition of strong support for scientific leadership gradually has been curtailed in hard economic times. In the last dozen years, for example, research and development as a fraction of our GNP had dropped by 19%, while the number of scientists and engineers engaged in R & D as a fraction of the labor force dropped 9%. In addition, R & D as a fraction of the federal budget has decreased 36%. Basic research, as a fraction of the federal budget, has decreased 27% and, as a fraction of the GNP, has decreased 16%. And finally, investment of industry in basic research as a fraction of net sales is down 32%. The bitter irony of this situation is that, at the same time America is retreating from its commitment to science and technology, its economic and ideological competitors are embracing science.

News stories, reports, and monographs all speak to trends in the Soviet Union, Japan, and Germany toward a surpassing technological edge more striking than in the educational preparation of students for both scientific and non-scientific careers requiring technological know-how. In these countries, <u>national policy</u> promotes the comprehensive science and mathematics education of far greater numbers of people than are expected to engage in scientific and engineering pursuits.

In Japan, one of our chief economic competitors, the number of degrees granted to engineers in recent years has surpassed the number granted in those same years in the United States--even though Japan's population base is roughly one-half that of the United States. In Germany, another competitor, science instruction is begun in the third grade. Calculus, which a total of about one-half million Americans take during the last year of high school or the first year of college, is a part of the standard high school curriculum for five million students in the Soviet Union.

What is clear from these facts is that, in countries with which we compete economically or ideologically, there is a strong national commitment to include quality science and mathematics instruction as an essential part of the pre-college education process. It appears that in the United States there is now no such national commitment and, as a result, the United States, for the decade of the 1980's, is ill-prepared to provide the following: freedom from fear, i.e. national security; freedom from want, i.e. food and fiber; freedom from disease, i.e. health, and freedom from privation, i.e. energy for all of its citizens. The nominal reasons given are that we have grave shortages in investment, in resources, and in trained manpower. These are shortages that lie on the supply-side of the economy and, indeed, it is proper and necessary that supply-sided issues be addressed at the highest national policy levels. If we can agree that constraints on resources--constraints on supply--are the limiting factors to the achievement of national goals, then the policy question is more technical in nature and becomes one of how can we, as a nation, increase the resource base to give us more defense services, more food and fiber, more health services, and more energy supplies.

When economists are hard-up in their efforts to understand a large and complex modern industrial economy, they frequently resort to studying the simplest economy conceivable--a "Robinson Crusoe" economy. A single survivor washed up on a desert isle. Let's say that he needs 10 fish per day to live and he can catch 10 fish per day with his hands. Obviously, he suffers from severe constraints on his resources. From experience, however, he learned and reasoned that if he had new resources in the form of some kind of fish net or fish trap, he could increase his productivity and the quality of his life. He was so busy catching his 10 fish, though, that he had no time to do research, to teach himself, or to construct this new capital resource. Thus, he reasoned that for some period of time he could probably live on eight fish per day if he cut his consumption; thereby, he could save two fish per day. Doing this for five days he could accumulate 10 fish and could live off this catch while he did research and experimentation on fish catching. And so he did. His fish trap was so successful that in one day he could catch enough fish for a week. That left him with six days to improve his defense security, his living conditions, and his research and resource base.

The lesson in this story is that the resource base can be expanded, regardless of circumstance. It is expanded by research and education and application. A nation that wishes to provide for its national security--the common defense--and to to promote the general welfare, is well-advised to

plan prudently to increase its investment in research and education. We can overcome the present limitations and constraints of our resource base. We can provide for our material future.

And what of our spiritual future? My reply is a simple mixture of hope and faith. I hope that when relieved by federal assistance of the substantial burden of providing the laboratories, the equipment, the libraries, technicians, and teachers for the giant step of science into the future, university presidents and chancellors, faculty and governing boards will be able to reallocate funds within the university to support the social sciences and humanities and arts in ways and at levels appropriate for this high tech-post industrial society. Indeed, whether in the event of great success or crashing failure in science, we must know that men and women do not live by bread alone. This belief is so deeply rooted in the mentality of the academic community that I have faith it shall always continue to flourish. And this faith is related to observation and experience in the Indonesian setting, the one radicalizing event in my life which heretofore did not seem relevant to today's problems.

The Indonesian culture, principally that of Java, is more than 2,000 years old. The first priority is, and always has been, the cultivation of rice. Rice is enshrined in the goddess of rice, Dewi Sri. The language has more than 20 different words for rice in its forms and uses. The second priority is and always has been the cultivation of the senses--in art, in dress, in dance, in music, in drama, in epic stories, and in shadow puppet plays. Unlike the West, with its preoccupation with time, the Indonesian culture stresses experience, life's meaningful events--birth, circumcision, marriage, death, and Friday morning at the Mosque.

In my years within that Asian culture, I learned something very precious about life's continuity and its unchanging cycles of renewal through closeness to the past as well as to the present moment. And so today, I hope, in our rush to embrace a future of science and technology, we will forget neither our common sense nor our senses.

SOIL CONSERVATION RESEARCH AND USE OF RESEARCH INFORMATION

BY THE SOIL CONSERVATION SERVICE

by

RALPH J. McCRACKEN

There is considerable concern today about America's soil and water resources. Concerns have been expressed about soil erosion, our supply of farmland, the supply and quality of water used in agriculture, and other resource problems. These concerns, especially soil erosion, have been widely reported in newspapers and other news media, popular books and articles, and technical and scholarly journals.[1] Congressional concerns are reflected in the Soil and Water Resources Conservation Act of 1977 and a study by the Office of Technology Assessment on the impacts of technology on cropland and rangeland productivity.[2]

Soil Erosion

Soil erosion could be the major long-term natural resource problem we face. It weakened and contributed to the downfall of the great ancient civilizations--Rome, Greece, North Africa. Erosion has recently increased in many of our best agricultural areas. Three major factors are behind the increase. First, farmers are planting a higher proportion of row crops, notably corn and soybeans, and a lower proportion of soil-protecting hay and small-grain crops. Second, they are row-cropping more marginal land--steeper and more erodible soils--to increase exports and farm income. Third, farmers are using larger machines to grow crops and, in some cases, these machines are not compatible with previously installed conservation practices such as terraces that were designed for farming with smaller machines. As a result, land that previously was protected from erosion is now more vulnerable.

Nationally, crop yields per acre continue to rise slowly, largely because the effect of erosion on soil productivity so far has been offset by technology--chiefly increased use of fertilizers, improved crop varieties, and greater use of pesticides. Another major offsetting factor has been the use of larger and more efficient tractors and other machines for planting and harvesting crops which have resulted in more timely farming operations. In the Corn Belt, for example, average yields of corn have increased from 50 to 60 bushels per acre in the 1950's to more than 100 bushels today. Some Corn Belt soils, however, have irreparably lost much of their inherent productivity because of topsoil erosion, especially soils with rock or with impervious or sandy and gravelly layers near the surface. Many other

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soils are approaching the threshold beyond which their productivity will become irreparably damaged. Meanwhile, as the cost of crop production has risen relative to farm income, cash-short farmers have found themselves hard pressed to make needed investments in conservation. Inadequate soil management acts as a destructive force, demanding high production from the soil while weakening its long-term capacity to produce.

More research and better use of research results are needed so that land users can apply essential soil conservation practices that are both effective and affordable.

Land Use

Concerns about America's soil resources include problems of quantity as well as quality. A significant amount of agricultural land has been converted to urban and water use. From 1967 to 1975, about 23 million acres of nonfederal rural land were converted to urban and water uses; about eight million of these acres were prime farmland. Our total supply of potential as well as current cropland is approximately 540 million acres.[3] Some believe that our reserve of potential cropland is adequate, and that the marketplace should determine the value and best use of land.[4] Information on the availability of agricultural land will be updated in September 1983 when the Soil Conservation Service plans to issue its 1982 National Resources Inventory.

Water Resources

Agriculture will continue to be a heavy user of water resources, and this use will increase. Irrigation alone now accounts for more than 80 percent of all water consumption.[5] Shortages of water for agriculture are likely to be of great concern in the future--including the humid Southeast where the acreage under irrigation is increasing. In parts of the Great Plains, ground water from the Ogallala Formation is being "mined," that is, it is being withdrawn for irrigation faster than it is naturally being replenished.[6]

Along with actual and potential water shortages, the nation also has problems of too much water--from upstream flooding. Upstream floods are those that occur in drainage basins of less than 400 square miles. In 1975, damage from upstream flooding was $1.7 billion (constant 1975 dollars); in the year 2000, the damage is projected to reach $2.3 billion.[7]

Natural Resource Inventory and Assessment

As previously mentioned, concerns about soil erosion and water conservation led to passage of the Soil and Water Resources Conservation Act of 1977 (RCA). The RCA required the Secretary of Agriculture to appraise on a continuing basis the nation's nonfederal soil, water, and related resources and to develop and to update periodically a program for conserving those

resources. USDA has completed its comprehensive appraisal and is completing the final program.[8] The President is expected to submit the program, along with a statement of policy, to Congress soon.

Before Congress passed the RCA, SCS had begun a National Resources Inventory complete with data as of 1977 from which the RCA appraisal drew heavily.[9] SCS is now completing a 1982 NRI inventory as required by legislative mandate. In the RCA program as proposed by USDA, the first priority is to reduce excessive soil erosion and nonfederal cropland, pastureland, rangeland, and forest land. The second priority is two-fold: to conserve water used in agriculture and to reduce damage from upstream flooding. At local and state levels, further priorities will be set in addition to these national priorities and other resource concerns of national significance. The RCA national priorities set the basic tone of needs for conservation research and development.

Research Needs

To signal specific needs for research by USDA agencies and to promote liaison with them, SCS has established a national research committee. The SCS committee recently issued a set of research and educational needs that address the major resource concerns. These are listed below in the order of importance assigned to them by the committee:

1. Accelerate extension efforts relating to conservation tillage;

2. Continue, and expand as funding permits, research to determine the potentials and limiations of various soils for conservation tillage;

3. Accelerate research to develop an erosion-soil productivity model;

4. Develop alternatives for economically treating large active gullies and for water management strategies to prevent gullies;

5. Continue development of methods for estimating effects of soil and water conservation practices on flood runoff;

6. Accelerate research to develop crop varieties tolerant of flooding;

7. Continue research to determine optimum use and timing of irrigation for various crops, soils, and climates;

8. Accelerate the transfer of information obtained from reserach on irrigation and drainage;

9. Determine effects of high-intensity grazing systems on plant communities, wildlife populations, livestock production, and water yield quality.

In addition, SCS needs information about completed research available for development and application and about current research that appears promising. Effective agricultural research will continue to rely a great deal on close communication between government agencies and private organizations. In 1981, for example, a consortium of 10 agricultural, scientific, and technical societies held a national workshop on conservation research. The workshop was supported by funds supplied by several USDA agencies, the Department of the Interior, the Tennessee Valley Authority, the Farm Foundation, and the Wildlife Management Institute. A publication that resulted from the workshop is a comprehensive treatment of current research progress and opportunities in soil, water, and related resources on forest land, rangeland, urban and recreation areas, and drastically disturbed land.[10] The top priority research goals identified by the workshop are as follows:

1. Sustaining soil productivity;
2. Developing conservation technology;
3. Managing water in stressed environments;
4. Protecting water quality;
5. Assessing soil and water resources.

Applying Research Results on the Land

How do SCS field conservationists and technicians get the research-based information they use to help land users apply conservation on the land? The chief means are SCS manuals and handbooks, soil survey maps and reports, and interaction with SCS technical staffs.

Research information produced by other USDA agencies, state agricultural experiment stations, and others is used by SCS headquarters staff in Washington, D.C., and technical staffs of the four SCS national technical centers (located in Portland, Oregon, Fort Worth, Texas, Lincoln, Nebraska, and Broomall, Pennsylvania). These staffs act as liaisons between the sources of research knowledge and those who will use it for applying conservation treatments in the field. Research-based information is also incorporated in SCS handbooks, manuals, and bulletins that are distributed service-wide. These materials are updated as necessary.

The SCS national research committee also maintains a dialogue on research needs with scientists and staff of USDA research agencies, especially the Agricultural Research Service (ARS). In turn, ARS representatives and others inform SCS about research results and current and planned research, especially research that applies to priorities set through the RCA appraisal.

How do farmers and ranchers tell SCS about their conservation problems and research needs? Mostly, they discuss these matters with personnel at SCS field offices and local soil and water conservation districts. The nation has nearly 3,000 of these districts. While SCS supplies technical assistance to these districts, they are managed by elected boards of supervisors and have formed state, regional, and national organizations through membership in the National Association of Conservation Districts (NACD). NACD has a research committee at the national level and in each of its regions. The NACD committees relay their perceptions of research needs to ARS, other research organizations, and SCS.

Other Research Needs

Several other research needs recently have risen in priority or have been identified as SCS has conducted the 1982 National Resources Inventory and accelerated its efforts in getting conservation applied on the land:

1. Ephemeral Concentrated Flow Erosion--This is water erosion caused by the joining of rills. The resulting channels are smaller and account for less soil loss than gullies but the loss is significant. The channels are erased by the heavy tillage equipment many farmers now use. Concentrated flow erosion is caused by heavy early spring rains on bare soil, by rapid short-term runoff of snowmelt, and by concentration of irrigation water between crop rows. It is not adequately accounted for in the Universal Soil Loss Equation which USDA uses to estimate sheet and rill erosion.[11] This type of erosion is found to be common in many parts of the country.

2. Soil Loss Tolerance--This concept needs to be reexamined. In theory, soil loss tolerance is the maximum average annual rate of erosion (in tons per acre) at or below which soil productivity can be sustained over time. There are differences, however, in the basis for and definition of soil loss tolerance. For example, should the tolerance (T) value be based solely on on-site rates of soil genesis or topsoil formation, or should it reflect off-site concerns such as sedimentation that affects water quality?[12] T values are very important in conservation planning because they establish the target level of erosion control for proposed conservation systems.

3. Research and Development on Remote Sensing--Most inventory and assessment data must now be obtained manually during field visits. This is expensive and time-consuming and SCS needs more efficient and accurate remote sensing methods to support data collection.

4. Improvement of Data Storage and Retrieval--Maximum compatibility and better coordination are needed among the separate natural resource databases of federal and state agencies, universities, and other organizations. In addition, those containing literature citations and abstracts need a well-structured thesaurus to aid search capabilities. These items are needed to support and facilitate soil and water research and to aid in the use of research results.

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THE NATIONAL FORESTS AND

THE CAMPAIGN FOR WILDERNESS LEGISLATION

by

DENNIS ROTH

Is not the pastness of the past the profounder, the completer, the more legendary, the more immediately before the present it falls?... Not all in a minute, then, will the narrator be finished with the story... The seven days of the week will not suffice, no nor seven month either. Best not too soon make too plain how much mortal time must pass over his head while he sits spun around in his spell. Heaven forbid it should be seven years!

Thomas Mann, The Magic Mountain, trans. H.T. Lowe-Porter (New York: Vintage Books, 1969), preface.

The passage of the Wilderness Act of 1964, after seven and a half years of legislative struggle, marked the first time in human history that wilderness areas were given specific statutory protection without, at the same time, closing them to human access. The Act potentially applied to all federal lands with wilderness characteristics but the largest percentge of such areas were administered by the Forest Service in the Department of Agriculture. Moreover, these lands were subject to stronger and more varied interest-group pressures than other undeveloped federal lands. Thus, the history of the Wilderness Act is largely the history of the politics of the National Forest wilderness areas.

Before the end of the second decade of our century, wilderness conditions existed as a by-product of Americans' desire to preserve scenic wonders in national parks and to reserve from the public domain some forests and mountain ranges so that watersheds and future supplies of timber could be protected. Wilderness as a land type did not exist in its own right but was imbedded in other land management categories.[1]

Of course, nature enthusiasts, such as John Muir, valued wilderness for itself and strove to protect what little remained of it after three centuries of westward expansion, settlement, and commercial exploitation.[2] The passage of the National Park Act in 1916, two years after his death, partially rewarded his efforts. This act, however, was partly contradictory for it called on the newly-created National Park Service in the Department of the Interior to protect the natural integrity of the parks, yet make them available for use and public enjoyment.[3] In 1916 this was only a potential contradiction, for the automobile was still a novelty and park tourism only a fraction of what it would become a few decades later, but this mandate was probably the reason why the Park Service did not pioneer in wilderness management planning. Although the Forest Service in the Department of Agriculture had not been specifically charged with promoting public enjoyment of the national forests in the Forest Reserve Organic Act of 1897, it was there that the idea of managing land for its wilderness values first took shape.

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Aldo Leopold was a young forest supervisor at the Carson National Forest in New Mexico. He was an eastern-trained intellectual forester who loved to ride the backcountry and hunt. As early as 1913, he had discussed with Elliot Barker, one of his rangers at Carson, the idea of setting aside wilderness areas.[4] By the end of World War I, Leopold had become apprehensive that as more and more roads made their way into the backcountry they would destroy the wilderness which he valued as the forge that had created the American national character and where he believed it could only be renewed. Leopold also was inspired by the new science of ecology which considered wilderness as the ideal laboratory within which to study the operation of natural processes.[5] In 1918 the Ecological Society of America was formed and, in 1920, Francis B. Sumner wrote an article urging the Society to back the setting aside of untouched areas.[6] In 1921 Leopold first drew the attention of professional foresters to the wilderness idea in a Journal of Forestry article and suggested that a wilderness of at least 500,000 acres be established in each of the 11 states west of the Great Plains.

In May of 1922 Leopold, who had been promoted to Assistant District Forester in 1917, made an inspection trip into the headwaters of the Gila River. Soon thereafter he wrote a wilderness plan for the area that excluded roads and additional use permits except grazing. Although it did allow for trails and telephone lines needed in case of forest fires, Leopold's plan encountered opposition from some of his colleagues in the District office who thought that development should take precedence over preservation. On June 3, 1924, however, District Forester Frank Pooler approved Leopold's concept. The Gila area was to be placed under a ten-year wilderness recreation policy. Roads were to be limited and efforts were to be made to acquire private holdings through land exchanges. Grazing and water power developments were not to be impeded. Pooler's action did not carry any immediate national significance because the Forest Service's Washington office was not involved in the decision.[7]

Leopold looked at wilderness with the eyes of a hunter and budding ecologist. In 1919 the Forest Service hired its first landscape architect, Arthur Carhart, who was to emphasize the aesthetic and recreational benefits of a policy of non-development. Carhart was assigned to the District Office in Denver. That summer he was asked to survey the Trappers Lake area in the White River National Forest in Colorado for summer home sites. While laying out his survey lines, he came upon two wealthy hunters, Paul J. Rainey and William McFadden, who convinced Carhart that Trappers Lake should remain wild and that houses and roads should be excluded from the vicinity of the lake. Carhart's training as a landscape architect and his affinity for unspoiled nature made him receptive to this argument. As a result, he developed a functional recreational plan to preserve the pristine conditions at Trappers Lake. Carhart convinced his superiors to halt plans to develop Trappers Lake marking, in the words of Donald Baldwin, a supporter of the proposition that Carhart and not Leopold first formulated the wilderness concept, "an unprecedented step in Forest Service history."[8] (Leopold

was at least thinking about the wilderness concept in 1913, six years before Carhart joined the Forest Service. In addition Mike Nadel, former editor of The Living Wilderness, has argued in a phone conversation with the author that Leopold's developing ecological approach was more consistent with the modern wilderness concept than one based mainly on aesthetics).

Carhart later surveyed the lake region of the Superior National Forest in Minnesota. Again he recommended that development be minimized and that the area be preserved as much as possible for primitive canoe travel. On September 9, 1926, the Secretary of Agriculture signed a plan to protect this area which, in 1964, became known as the Boundary Waters Canoe Area. Carhart left the Forest Service at the end of 1922 and Leopold departed two years later for the Forest Products Laboratory, thus leaving the implementation of their wilderness philosophy to others.

Forest Service annual reports from 1921 to 1929 reflect an increasing awareness of the importance of recreation and, beginning in 1926, single out wilderness for separate discussion. According to Chief William B. Greeley in 1926, the wilderness idea "has merit and deserves careful study, but its correlation with the other obligations and requirements of National Forest administration must be carefully worked out before definite steps are taken to give any areas a wilderness status." One year later Greeley was writing more positively about wilderness areas: "The Forest Service plans to withhold these areas against unnecessary road building and forms of special use of a commercial character which would impair their wilderness character."[9]

In 1926 Greeley and Assistant Forester for Lands Leon Kneipp ordered an inventory of all undeveloped National Forest areas larger than 230,400 acres, i.e. ten townships or more. Three years later wilderness policy assumed national scope with the promulgation of the L-20 Regulations covering so-called "primitive areas." These regulations were to insure that the objective of management would be "to maintain primitive conditions of transportation, subsistence, habitation, and environment to the fullest degree compatible with their highest public use with a view to conserving the values of such areas for purposes of public education and recreation." A management plan was to be prepared which would show the extent to and conditions under which the timber, forage, or water resources would be utilized, permanent improvements constructed, and special use occupancy allowed.[10]

According to James Gilligan, whose 1953 doctoral dissertation was to play an important role in the devlopment of the wilderness bill, these regulations were simply strong recommendations to Forest Service field personnel to limited unplanned development in untouched areas. They did not categorically prohibit any form of development or use, and, consistent with the Service's decentralized style of administration, gave a great deal of discretion to field personnel. This was reflected in the fact that as late as 1953 logging, grazing, and roads had been totally excluded from only four primitive areas although, by 1939, some 14 million areas had been designated as "primitive."[11]

Historians have suggested that the Forest Service had two primary reasons for recommending the L-20 Regulations: (1) to discourage field personnel from rushing into unneeded and unplanned development; (2) to help prevent the transfer of more land to the Park Service.[12] Ever since the creation of the Park Service in 1916, the national parks had been carved largely out of national forest acreage. But now its primitive areas allowed the Forest Service to show that it too was interested in preserving wild regions and that land transfers to the Park Service were no longer necessary.

Some Forest Service officials, have denied that this was one of the motives behind the L-20 Regulations because many primitive areas were eventually transferred to the Park Service.[13] However, it is possible that the designation of primitive areas forestalled the creation of even more parks. For example, the Park Service sought vainly yet at length for a park in Idaho where the Forest Service had large primitive areas, now part of the River-of-No-Return Wilderness. The lack of an acreage minimum placed on primitive areas has been interpreted by some as an intent to discourage the creation of parks. Leopold had suggested 500,000 acres and Kneipp had asked for an inventory of areas of 230,400 or more acres but, under the L-20 Regulations, many smaller areas were classified as primitive.[14] There is no record that explains this change and the suspicion persists that it was an attempt to encompass any area that might have national park potential.[15] On the other hand, it may have been an early recognition by the Forest Service that wilderness values can be protected in areas of smaller size.

The rivalry of the two Services was reflected in their terminology for undeveloped areas. In the 1920's the Forest Service called its areas such as the Gila, "wilderness," while the Park Service called its backcountry "primitive." When the USDA Forest Service came out with its L-20 Regulations covering "primitive areas," the Park Service switched to "wilderness."[16]

Preservation organizations, such as the Sierra Club and the Wilderness Society (founded 1935), were able to take advantage of this inter-service rivalry. Naturally, the Park Service received its strongest support from preservationists but the Forest Service could not ignore them unless it was willing to risk losing land to parks. It could even cultivate these groups by asserting that it did not clutter its primitive areas with recreational developments which, by the late 1930's, many preservationists were finding disturbingly prevalent in the national parks.[17]

Perhaps the most skillful exploiter of this situation was Robert Marshall, son of a wealthy New York attorney, who dreamed of wilderness exploration and hiking in the Adirondacks while growing up on Park Avenue. Afraid that he had been born too late to emulate his boyhood heroes, Lewis and Clark, he felt compelled to climb every peak and explore every wilderness he could before his sudden death of heart failure in November 1939 at the age of 38. After a short stint in the Forest Service, he earned a Ph.D. in plant

physiology, and became Chief Forester for the Bureau of Indian Affairs where he established a system of Indian wildernesses. From his position with the Department of the Interior, he exhorted the Forest Service to increase its primitive acreage.

In 1933 Marshall authored the recreation section of A National Plan for American Forestry (the so-called Copeland Report). He recognized that wilderness would primarily be in the high country where commercial values were low. At that time he believed that logging could be permitted in some instances, a view he would not hold a few years later, and that grazing, water storage reservoirs, telephone lines, and fire control cabins were compatible with wilderness.[18]

In 1935 he was one of the founders and benefactors of the Wilderness Society. From 1931 to 1938 the amount of primitive acreage increased from four to fourteen million. How much of this was due to Marshall's advocacy, how much to Forest Service advocacy of the wilderness concept or fear of more parks, and how much to preservationist sentiment from within its own ranks is impossible to say.[19] Marshall pressed his conservation-minded boss and friend, Secretary of the Interior Harold Ickes, for a stronger Park Service commitment to wilderness preservation. Ickes wanted to gain control of the Forest Service and transfer it to a new Department of Natural Resources under his leadership. But if he could not get that much, then at least he wanted to expand his domain at the expense of the national forests. Thus, Ickes was disposed to listen to Marshall and, in 1939, he proposed legislative protection for park wilderness. This plan died, however, primarily because the National Park Association, the Park Service's main support organization, was afraid that special protection for park wilderness would result in the degradation of heavily used areas of the parks.[20] Marshall left Interior in 1937, disappointed by what he saw as the Park Service's growing attachment to recreational developments, to head the Forest Service's Lands Division, just renamed Recreation and Lands. Marshall constantly sought stronger wilderness protection from Chief Forester Ferdinand Silcox.

In 1939 the U Regulations, drafted by Marshall and approved by Silcox, supplanted L-20. They afforded much greater protection to wilderness areas, absolutely prohibiting motor boats or the landing of aircraft (except where such uses were well established or were needed in emergencies or for administration), timbering, road construction, special use permits for hotels, stores, resorts, summer homes, organization camps, and hunting and fishing camps, etc. The grazing of livestock was permitted, as it had been under L-20, because the stockmen would have vigorously and perhaps successfully opposed any ban. Water storage projects were also permitted if they did not involve road construction, as were improvements necessary for fire protection, both remaining "subject to such restrictions as the Chief deems desirable." Forest Service wilderness areas, like the rest of the National Forest System, had not been withdrawn from the operation of the

mining and leasing laws and the possibility of reservoir and dam construction. The Forest Service could only insist under the U Regulations that such developments be undertaken with a minimum of damage to the wilderness environment.[21]

In many instances, primitive areas had been created without adequate surveys. Thus, under the U Regulations, all primitive areas were to be re-evaluated before they could be reclassified by the Secretary of Agriculture as "wilderness areas" (100,000 acres or more) or by the Chief of the Forest Servies as "wild" areas (5,000 to 100,000 acres). In addition, the public was given the opportunity to comment 90 days before any proposed reclassification. Meanwhile, primitive areas were to be given the protection of the U Regulations.[22]

In his brief two and a half years with the Forest Service, Marshall had succeeded in strengthening its wilderness policies but he had become disenchanted at the slow pace of reclassification and the failure to enlarge the potential bank of wilderness areas beyond the fourteen million acres it had reached in 1938. Before his death, he was considering leaving the Forest Service in order to apply pressure on it from outside the government.[23]

Despite the preservationists' success in playing one Service off against the other, they entered the post-World War II era with a growing feeling of uneasiness over the long-term security of wilderness areas. With the death of Bob Marshall, they had lost their most inspirational leader and the one man who successfully had bridged the gap between the natural resource bureaucracies and the citizen preservationists. The end of the Depression and the War brought more people to the national parks and increased the demand on the Park Service for more recreational facilities, while the revived national economy made business and labor clamor for the commodities supplied by the national forests.

The period from 1905 to the end of World War II has traditionally been called the "stewardship" era of National Forest administration. Until the 1920's the Forest Service earned more in receipts from grazing fees than it did in timber contracts. By the mid-1920's timber had become the Service's biggest money earner but the amount that was being cut was an insignificant percentage of the potential harvest. Many roadless areas were preserved in their pristine state becuase there was simply no demand for their resources. By the end of World War II many private timber owners were discovering that they had overcut their own lands and were now looking to the national forests to supply their needs. Areas that were once considered uneconomical to harvest were becoming profitable. The Forest Service was entering an era of intensive management and involvement in the market economy. Faced with these demands on the parks and forests, preservationists were anxious about the continued existence of wilderness based on administrative protection alone since what one administrator could do, another could undo. They especially feared policy changes by new leaders in the Forest Service which

had been established to manage resources on a multiple-use, sustained-yield basis. (These expressions were not used before the 1930's but others used earlier, such as "the greatest good for the greatest number" and "wise use," had essentially the same meaning). Foresters, after all, were trained to use conservatively forest resources, not to preserve them. That some foresters in the first half of this century changed their views after going to work was testimony more to their flexibility and to their openness to experience than to the nature of their academic training. Moreover, the preservationists distrusted the decentralized organization of the Forest Service which worked admirably in allowing its personnel to adjust to local social and economic conditions but which, they felt, militated against the application of uniform standards for the protection of the fragile wilderness resource.[24]

The importance which preservationists attached to uniform standards becomes apparent when it is recognized, as Michael McCloskey pointed out in an article analyzing the provisions of the 1964 Wilderness Act, that they especially value the "mental image" of a pristine wilderness.[25] (He counseled wilderness managers to keep this in mind when interpreting the intentions of the drafters of the Act). Working foresters often look upon environmental changes as subject to the recuperative powers of nature, while preservationists abhor them as a threat to the idea of purity and absence of human manipulation which sustain their image of wilderness.

All of these structural defects that the preservationists perceived in wilderness management of the 1940's and early 1950's became focused on the issue of primitive area reclassification. They had applauded the Forest Service when it placed all primitive areas under the U Regulations but doubts soon began to be expressed over the process of reclassification. Partially because of the curtailment of many activities during World War II, primitive areas were being reclassified at a slow rate (only 2,000,000 acres had become wilderness by the late 1940's). Some preservationists claimed that when they were reclassified it sometimes happened that timbered areas in lower elevations were removed. The Forest Service could point out that the total primitive acreage had remained stable but the preservationists countered that this had been done by substituting non-timbered, rocky terrain at the highest elevations, thus degrading the quality and variety of the wilderness areas.[26] Although he did not cite any evidence, Gilligan stated that the Forest Service was shrinking the size of large primitive areas by breaking them up because its personnel observed that the smaller areas, which were accessible by road, experienced greater proportional recreational use.[27] One preservationist wag opined that the Forest Service had decreed a wilderness policy of "no timber harvesting above timberline."[28]

Perhaps the most well-known example of the defects of reclassification took place at the Willamette National Forest in the mid-1950's when 53,000 acres of timbered land at lower elevations were removed from the Three Sisters Primitive Area. This action aroused the ire of Oregon's junior senator,

Richard Neuberger, who soon thereafter became co-sponsor with Senator Hubert Humphrey, the most ardent congressional advocate of the wilderness bill during the first four years of its legislative history before the Oregonian's death from cancer in 1960.[29]

The preservationists were aware that the Forest Service was under pressure from local economies to increase the amount of land available for timber harvesting. Ever since the creation of the national forests in the late nineteenth and early twentieth centuries, Forest Service administrators had been sensitive to the criticism levelled at them by many westerners of "locking up" resources. Thus, the preservationists began to explore ways in which the Forest Service and the Park Service could successfully resist development pressures and give free reign to their best wilderness intentions. In addition, the preservationists felt they had to combat what they perceived as a deterministic belief common among foresters that however worthwhile wilderness preservation might be, it must give way to economic development.[30]

Preservationists knew that economic development would have to be allowed in some remote areas. They were aware that wilderness areas not covered by the U Regulations (called "de-facto" wilderness after the passage of the 1964 Wilderness Act) were disappearing at a rapid rate. (In 1968, Albert Dixon estimated that at least 35,000,000 acres of de-facto wilderness in the National Forests were developed between the Kneipp survey of 1926 and 1960).[31] The preservationists, however, differed with the determinists in that they believed that many such "de-facto" areas should be preserved by Congressional action. Otherwise, development would be inevitable. This conviction later became the philosophical preamble of the Wilderness Act:

> In order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify, all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition, it is hereby declared to be the policy of the Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness.[32]

In 1946 Howard Zahniser of the Wilderness Society began his missionary effort by criticizing a national Forestry plan presented at Higgins Lake in Michigan and by calling for the zoning as wilderness of certain areas of "primitive America."

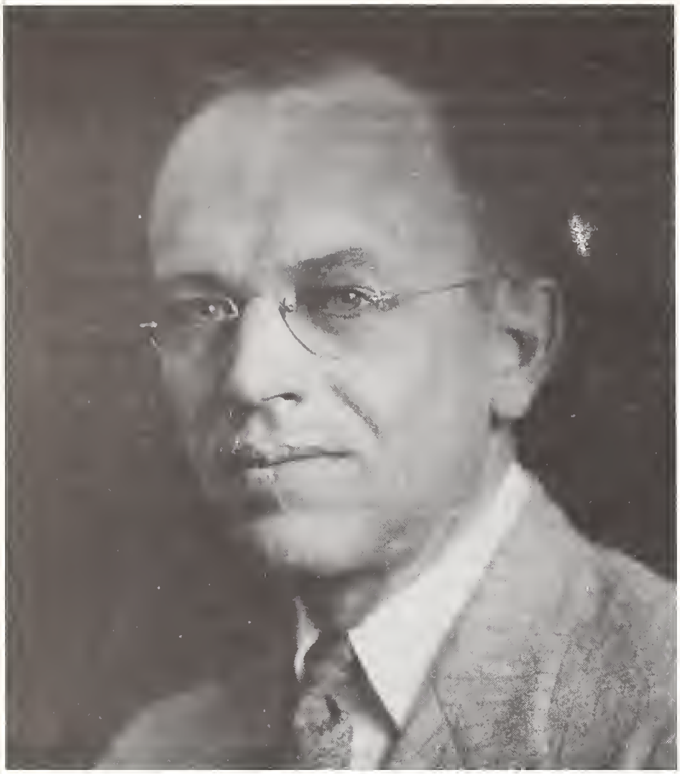
> If the Higgins Lake program and the appraisal report are simply steps to rationalize a further exploitation of American forests, with an up-to-date terminology, perhaps it is presumptuous to point out something that was planned that way. In these circumstances we should reluctantly have to charge our expectations up to disillusionment and enter a prolonged period of fighting for wilderness preservation with our guard up whenever 'good forestry' is mentioned....
>
> Nor is it an extravagant demand that is being made. The demand is simply this. Let us zone certain remnants of primitive America as wilderness areas, and then let us plan our sustained yield programs without figuring these areas into our working capital for future cuttings.[33]

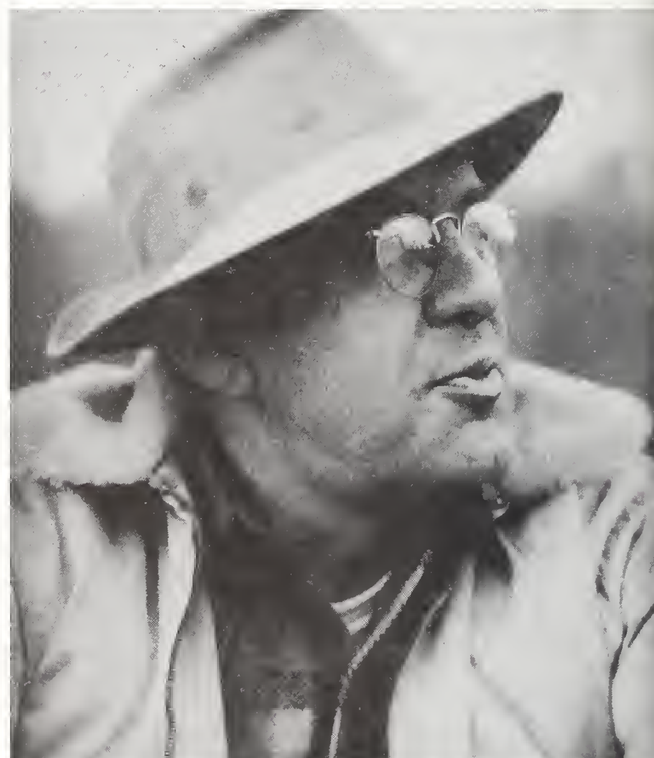
By zoning Zahniser was probably thinking of some form of compulsory legislation, though he did not say as much to the foresters, for this is what Aldo Leopold had charged him with seeking when he was hired as Executive Secretary of the Wilderness Society (later becoming Executive Director) and editor of its publication, The Living Wilderness, in 1945.[34]

Zahniser was born in Franklin, Pennsylvania in 1906, the son of a "free methodist preacher," to which he attributed the evangelical fervor with which he pursued the wilderness cause.[35] He joined the Federal Government in 1930 and from 1931 to 1945 served as a writer/editor/broadcaster (today he would be called a media specialist) in several conservation agencies. Then came the call of the Wilderness Society, of which he had been a member since its beginning, and with it a halving of his salary.[36]

Zahniser, Leopold, and Marshall form a triumvirate atop the pantheon of wilderness heroes. Since Marshall died in 1939 and Leopold in 1948 (at 61), Zahniser had to carry most of the burden of enunciating a philosophy and program of wilderness protection from the late 1940's until his own death at 58, a few months before enactment of the Wilderness Act.

Zahniser epitomized the growing number of people who were discovering the deep appeal of the wilderness after the Second World War. Not a back country adventurer like Marshall and Leopold, the "bald, bespectacled" Zahniser looked more like the stereotype of a librarian.[37] A bookstore was always his first stop when visiting a new city. Although he derived great inspiration from nature, as shown by his moving account of a trip to the Cloud Peak Primitive Area in Wyoming in 1947, he seldom found the opportunity to get away from work.[38] When he suffered a heart attack in 1952, he blamed himself for not taking his own advice on the therapeutic value of wilderness.[39] Zahniser's modest income made him more like a role model for the average wilderness lover than the caricature of wealthy, back-packing, elitists who were a prominent part of the demonology of wilderness opponents.





(Top Left, *Aldo Leopold about 1928*, Courtesy, the author; Top Right, *Arthur H. Carhart in 1961 at the Denver Conservation Library*, Courtesy, Denver Public Library, Western History Department; Bottom Left, *Bob Marshall*, Courtesy, the author; Bottom Right, *Howard Zahniser*, Courtesy, the author).

In a 1947 exchange of letters with Berkeley forestry professor, Frederick Baker, he expressed several of the philosophical themes that he would repeat over the next 17 years.[40] He was unwilling to accept Baker's fatalistic belief that wilderness would inevitably disappear nor his solipsism that wilderness is "within us" and need not depend on a pristine physical reality. For Zahniser, wilderness was also "within us," or a "mental image" in the words of Michael McCloskey, but that mental image was "itself dependent on the perpetuation of wilderness," just as, he might have said, the idealist philosopher, Plato, grounded his idea of beauty in the contemplation of beautiful forms.[41]

Zahniser likened wilderness areas to art museums, a simile he used many times in the following years.[42] Like the art museums, wilderness areas contained beauty which everybody might not see but which they nevertheless were glad was being protected. Even if only once in a lifetime they were able to see wilderness or great art, they could say, after Wordsworth, "'That in this moment there is food and life for future years.'"[43]

To Baker's argument that wilderness enthusiasts were only interested in the egoism of personal enjoyment and escapism, Zahniser countered that wilderness was also morally uplifting:

> This, it seems to me, suggests a fourth wilderness recreation value to the three you have so well outlined. To use your words, we might call it the 'essentially-within-us' value.
>
> Love of solitude, eagerness for adventure, and indulgence in romantic experience are, as you point out, the most common motives for 'fleeing to the wilderness' for recreation. Once there, however, many I believe experience a better understanding of themselves in relation to the whole community of life on earth and rather earnestly compare their civilized living with natural realities - to the improvement of their civilization.
>
> Some have deliberately come to value the wilderness most highly for this very purpose, and I believe they thus approach the nobility of aims which you perceive might otherwise be lacking, for they strive thereby to make of themselves better human beings and to contribute more to their human society....[44]

As Stephen Fox has suggested, this moral view of wilderness, which was not so evident before World War II, may have become more articulated as preservationists contemplated the implications of living in the nuclear age.[45] Nature must uplift man lest he destroy it along with himself.

In his exchanges with Baker, Zahniser displayed two personality traits which would serve his movement well. He was patient but determined, writing three

letters to Baker to elicit his views, and he was undogmatic. Although for him wilderness had a moral value, he recognized that "wilderness is properly a different thing to different people."[46] Both of these traits were essential to follow the wilderness bill for eight years through 66 rewrites and many compromises. Even then he "wore himself out" and, like Marshall and Leopold, died at a relatively young age (58).[47]

One of Zahniser's earliest tasks after joining the Wilderness Society was helping its Executive Director, Benton MacKaye, draft a bill to create "wilderness belts" throughout the United States.[48] According to the MacKaye plan, a nonprofit citizens group, supervised by a committee consisting of representatives from the Park Service, Forest Service, and the Fish and Wildlife Service, was to acquire with congressional appropriations land that would be reserved as wilderness and would not be subject to any form of development. This plan did not touch on the federal lands that were of the most concern to preservationists but it marked a beginning as the first specific proposal for a legislated national wilderness system. Congressman Daniel Hoch of Pennsylvania expressed interest in the bill but it was never introduced in Congress. Nevertheless, it gave Zahniser valuable practical experience in the mechanics of drafting a bill.

By 1947 the Wilderness Society had publicly favored legislative protection for federal wilderness areas but Zahniser withheld specific proposals until he had mustered a consensus of major conservation organizations. He did not want to risk a debacle like Harold Ickes had suffered in 1939. In 1949 he had his first opportunity to bring the issue of wilderness protection to the attention of conservation groups.

Through the good offices of Carl Shoemaker of the National Wildlife Federation, Zahniser persuaded Congressman Raymond H. Burke, Chairman of the Subcommittee on Wildlife Resources of the House Committee on Merchant Marine and Fisheries, to get the Library of Congress to conduct a study on America's wilderness needs. The study was assigned to Frank Keyser, an economist with the Legislative Reference Service, who sent questionnaires to federal agencies, states, and conservation organizations.

The Forest Service replied that mining and reservoir construction posed the largest threat to its wilderness areas but it stated that any course of legislative action needed further study. The more sanguine Park Service said it managed parks as units and kept recreational developments to a minimum. Its only suggestion for improvement was that more wilderness land should be transferred to its jurisdiction. The Fish and Wildlife Service, which managed the nation's wildlife refuges under authorities less clearly defined than those governing the Park Service and the Forest Service, favored the idea of some kind of national wilderness policy. After analyzing the responses, including a 46-page report from Zahniser, Keyser concluded that the majority opinion favored national legislation for wilderness. The report was published as a House Committee print and a limited number of copies were given to the Wilderness Society for distribution to those interested.

Keyser's report set the stage for Zahniser's first detailed proposal for legislated federal wilderness. This was presented at the second biennial Wilderness Conference hosted by the Sierra Club and included six points which he later included in the first wilderness bill:

> It should affirm the national policy to preserve such a wilderness system. It should define the proper uses of areas within the system and should provide for the protection of areas from inconsistent uses.
>
> Areas to be included in the system should be specified in the bill, and provisions for additions to the list of areas by executive order and formal designation by the Secretary of Agriculture or the Secretary of the Interior should be included, with the further provision that the removal of any area from the system can be effected only by Congress.
>
> The bill should make clear that no changes in jurisdiction would be involved and that no new land-administering agency would be established. The agency administering an area designated as a unit in the national wilderness preservation system would simply be charged with the responsibility of preserving its wilderness character....
>
> In other words, each area in the system would continue to serve the peculiar purpose that it has, or would have, in the program of its particular administering agency, but every agency would be charged with the responsibility of preserving the wilderness character of any area of the national wilderness preservation system in its custody.
>
> A commission or board should be set up to conduct a survey in cooperation with land-administering agencies, to recommend to Congress any necessary adjustments in this program, and to prepare --or coordinate the preparation of--maps and other materials for the information of the public with reference to this wilderness system.

By using the word "system," Zahniser emphasized that he favored comprehensive wilderness legislation and not a piecemeal "foot-in-the-door" strategy advocated by some preservationists. He was soon proved correct.

Before 1950, threats to wilderness had come in the form of recreational developments in the National Parks, which bothered preservationists but not many in the general public, and the gradual whittling away of land at lower elevations in Forest Service primitive areas, of whose existence very few in the general public were even aware. Nothing had as yet threatened to destroy a major element of the public's sacrosanct National Park System until a 1950 proposal was made by the Bureau of Reclamation to dam the Green River in the Dinosaur National Monument as part of the Upper Colorado River

Storage Project. This proposal rekindled memories of a bitter defeat that preservationists had suffered 40 years earlier--the Hetch-Hetchy Dam which had flooded a beautiful valley in Yosemite National Park.

The Dinosaur National Monument, an isolated area of stark beauty in northwestern Colorado and eastern Utah containing paleontological remains, had been reserved from the public domain by President Theodore Roosevelt under the Antiquities Act of 1906. It had been considerably enlarged by President Franklin Roosevelt and was administered by the Park Service. Although not a national park itself, which can only be created by an act of Congress, it was a part of the National Park System.

Preservationists were outraged by the proposal and carried on a five-year campaign to thwart it. By the time the proposal had been deleted from the Upper Colorado Bill in 1955, it had provoked more public opposition than any other previous one in conservation history. The public and preservationist organizations, skillfully mobilized by media specialists such as David Brower of the Sierra Club and Zahniser, responded not only to the possible damming of the Dinosaur National Monument but also to what they perceived as a threat to the entire National Park System. Moreover, it had been clearly demonstrated that, in the absence of an aroused public opinion, this system was defective in protecting wilderness values and that a new more comprehensive one was needed. The campaign has great educational value as well, for it had concerned an area as little-known as many of the Forest Service primitive areas and national wildlife refuges. Perhaps its very anonymity had allowed the public to see the need for wilderness legislation that may not have occurred had the dispute been over a more renowned part of the national park system.

As a result of this struggle, conservation organizations had become more united than ever, the need for wilderness preservation was not recognized by many in the general public, and Zahniser had gained not only many contacts in Congress but also the practical skills to lobby effectively for wilderness legislation. The time was ripe to introduce a wilderness bill in Congress.

In May 1955 Zahniser began an effort which James Sundquist said "followed the classic pattern for developing support for a bill."[49] Zahniser gave a speech to the American Planning and Civic Association meeting in Washington, D.C. in which he presented the philosophical arguments for wilderness preservation and repeated the specific proposals he had made in 1951. Senator Hubert Humphrey, who had been involved in the fight over the Dinosaur National Monument, inserted the speech in the Congressional Record. The Wilderness Society mailed reprints of the speech to its members and those in other conservation organizations under the franks of cooperative legislators. Humphrey was so impressed with the strength of the wilderness sentiment that he asked Zahniser for a bill. Zahniser, who may have wished to wait a little longer, began work on a bill in February of 1956.

By February 11 he had written the first complete draft of the bill and had begun to circulate it among a few leaders in the conservation movement. It contained seven sections but lacked the preamble (Section 2 of the Wilderness Act), which was added later to explain the philosophical premises of the bill.

Zahniser and his collaborators had incorporated the following three main concerns into the early stages of the bill's drafting: (1) They wanted it to be written in clear unambiguous language which was free of loopholes; (2) they wanted to maintain the coalition which had formed to protect the Dinosaur National Monument--thus, Zahniser was scrupulous in circulating the draft among the leaders of the major conservation organizations, and (3) they wanted to minimize opposition, a most difficult task which ultimately would take eight years to achieve. Behind these tactical considerations were the bill's four main objectives:

(1) to provide clear statutory authority for the maintenance of wilderness areas;
(2) to remove the administrative authority of Forest Service officials to decrease the size of or to declassify wilderness-type areas;
(3) to protect national wilderness against mining and the installation of water projects;
(4) to require designation of wilderness zones in units of the National Park system, federal wildlife refuge and range system, and within Indian reservations.[50]

In order to gain the support of the federal land managing agencies, the bill stated that existing jurisdictions would be respected and that it would not supersede the purposes for which the land was being administered, except to require that it was not a "reform" measure but one which Senator Humphrey would later point out, merely encouraged and gave legislative sanction to the good practices of the land managing agencies.

Zahniser attempted to blunt the opposition of commodity interests by assuring them that existing uses would be respected. But this could not be considered much comfort to stockmen, motorboatmen, or airplane pilots because their uses of wilderness were considered to be "nonconforming" and were to be terminated in a manner "equitable" to them. The bill contained language which could be used to enforce condemnations should the agencies be unable to reach voluntary agreements with the nonconforming users.

Much thought was given to two provisions which would be the most hotly contested in ensuring national debate and which would be primarily responsible for delaying the bill's passage for eight years. These concerned mining and the manner in which Forest Service primitive areas could be added to the wilderness system. (The wilderness and wild areas were to go immediately into the wilderness system.)

Zahniser had prohibited mining and prospecting in his first draft except on claims already made. Mining was also considered to be a "nonconforming" use and was eventually to be completely eliminated. In a later draft, Zahniser liberalized this section by allowing the President to open wilderness areas to prospecting and mining if needed for the common defense and security. (National Park wildernesses, most of which had never been open to mining, remained under the categorical ban). This was done to disarm critics who might charge that the wilderness system endangered national security. However, on the advice of former Forest Service Chief, Lyle Watts, this presidential authority was deleted and Zahniser reverted to his original position, thus making it the only "reform" aspect of the bill. Needless to say, mining interests became the most vigorous opponents of the wilderness bill.

In his first draft, Zahniser gave Congressional imprimatur to the Forest Service U Regulations. The only changes from previous practice were that only Congress could modify or eliminate wilderness areas through affirmative action of both houses and that the Forest Service was given until January 1, 1965 to reclassify all of its primitive areas "with such modifications in boundaries as the Secretary or the Chief of the Forest Service may make in each case upon reclassification of the primitive area as a wilderness or wild area." In a later draft, this procedure was dropped in favor of a "legislative veto." Under this scheme, an executive branch proposal to modify, eliminate, or create a wilderness area could be stopped by the majority vote of either house meeting within 90 calendar days of continuous session of the introduction of the proposal. This procedure was consistent with the preservationists' view that the Federal agencies usually did the right thing but had to be stopped when they went astray.

This change had the effect of increasing the executive branch's initiative and placing Congress in the role of a somewhat passive reviewer. As far as the preservationists were concerned, it combined the best of both worlds--fast and professional administrative action, unencumbered by legislative logjams or a committee chairman's power to delay legislation with Congress' ability to react quickly to public dissatisfaction with decisions that might be "contrary to conservation." To use a ceramic metaphor, the executive branch was to be the potter working the clay, while Congress would automatically fire the finished shapes or, with either one of its hands, destroy those which public opinion found to be defective.

Opponents of the wilderness bill were to argue that the use of the legislative veto was inappropriate in the case of public lands and was a surrender of congressional authority granted by the Constitution. They successfully pushed for affirmative action by both Houses of Congress. Underlying the constitutional debate, however, was one over how much land should go into wilderness. In 1963, Senator Henry Jackson succinctly stated the nub of the matter to one of his constituents:

"In my opinion, either way of doing the Congressional review gives the right of either House of Congress to block the recommendations of an area as wilderness. The real fight is between the conservationists' desire for a mechanism which will force Congress to act to keep an area out of the wilderness system, and the effort of the opponents to require Congressional action before an area gets in. The proponents want to prevent wilderness proposals from dying because Congress fails to get around to them. The opponents want to capitalize on delays and oversights to keep areas out. It is a struggle for tactical advantage...."[51]

At the end of February, 1956, copies of the draft bill were informally given to the Park Service and the Forest Service. Conrad Wirth, Director of the Park Service, replied that such a bill was not necessary and might even endanger National Park wilderness areas by lumping them together with those of other agencies.

The Forest Service opposed the provision establishing a Wilderness Commission (later changed to "Council"), which would monitor the agencies and act as their conduit to Congress. (After being watered down in later bills, the Wilderness Council was finally deleted in 1961). Its leaders also feared that other "special interests" would seek similar legislative guarantees for their uses of the national forests. In fact, one of the reasons the drafting of the bill had been delayed until 1956 was that in the late 1940's and early 1950's stockmen had come close to asserting virtual proprietary rights over national forest rangelands. That struggle was over by 1956 but it still remained fresh in the minds of Forest Service leaders.

Ironically, Arthur Carhart, one of the originators of the wilderness concept but a citizen of Colorado where the "range war" had been most intense, opposed the wilderness bill for that reason. Later David Brower of the Sierra Club would claim that the Forest Service had leaked its copy of the bill to commodity interests, but even if that had been true, it could not have had any real effect on the bill's subsequent history.

In early March the bill was introduced to a wider circle at the 21st Wildlife Conference in New Orleans, the major annual forum for conservationists. One month later it received its full public unveiling at the Northwest Wilderness Conference, sponsored by the Federation of Western Outdoor Clubs, which voted to support it and wrote Senator Humphrey urging its passage. Senator Richard Neuberger, impressed by the Federation's enthusiastic support of the bill, asked Senator Humphrey if he could be a co-sponsor. By the end of April support and opposition were coalescing for and against the bill. On June 7, Humphrey introduced it in the Senate as S. 4013. Because it was already late in the legislative session and with a presidential election coming in 5 months, it was introduced as a study bill. The full legislative process did not begin until February 1957 when Humphrey reintroduced it as S. 1176.

Summary History of the Use Provisions of the Wilderness Bill

Several historians have written of the progress of the wilderness bill(s) through the maze of hearings and past the delaying tactics employed by the bills' strategically placed opponents in the Senate and House Interior and Insular Affairs Committees until President Kennedy and House Committee Chairman, Wayne Aspinall, reached a compromise providing for affirmative action in exchange for interim protection of primitive areas. Interested readers are referred to these histories for a detailed chronology of the wilderness bill.[52]

Casualties of language litter the battlefields over public policy. In the case of the wilderness bill, the expression "multiple use" (meaning in foresters' parlance that combination of uses yielding the greatest public benefit) came close to linguistic extinction. To the bill's opponents (very few ever admitted open opposition to the abstract concept of wilderness), multiple use was a code expression for the exploitation of all commercial possibilities of the forests. Because it had been coined by practical foresters interested in using forest resources, preservationists usually went on the defensive when they heard it. When they did care to pronounce it, they meant all those uses of the land which were consistent with maintaining its wilderness character, i.e. scientific research, recreational and scenic enjoyment, educational enrichment, and watershed protection. In fact, Zahniser maintained that watershed protection was the "dominant" use of any wilderness area and that if wilderness users should threaten its watershed, their numbers and activities could be restricted.[53] Multiple use was rescued from a complete semantic muddle with the passage of the Multiple Use, Sustained-Yield Act of 1960, which recognized that "the establishment and maintenance of areas of wilderness are consistent with the purposes and provisions" of the Act.[54]

In the following, those sections of the bill(s) affecting major uses of National Forest wilderness areas are analyzed. Next to the question of affirmative action, these issues were the most important in the bills' legislative history. National Park wilderness, with some exceptions, had always been withdrawn from the possibilty of non-recreational commercial development and had the bill only been concerned with the parks, it would have encountered much less opposition, even though the Park Service did not fully accept the idea of statutory protection for its wilderness areas until the election of President Kennedy.

Wilderness in National Wildlife and Game Refuges was a somewhat more contentious issue because the bill contained language which some construed as allowing the President to create additional refuges which then could become part of the wilderness system if Congress did not legislatively veto the proposals. Commodity interest groups saw the specter of an "unlimited expansion" of wilderness areas created by presidential fiat and ratified by congressional inaction. In 1961 this procedure was limited to those refuges already in existence, which partially mollified the bills' opponents.[55] When the legislative veto was dropped in favor of

affirmative action, it applied to the creation of all park and refuge wilderness as well as to National Forest primitive areas.

Indian wilderness areas were included in the early bills but were deleted in 1961 when it became apparent that Indian tribes and the Bureau of Indian Affairs were strongly opposed, even when the bill gave tribal councils the right to veto the designation of any Indian land as wilderness. Bob Marshall had created an Indian wilderness system without getting the tribes' consent. Quite understandably, the tribes did not want any more federal interference with their wilderness lands.[56]

Zahniser once said that wilderness, like chastity, is defined by that which it negates.[57] The history of the wilderness bill is essentially the history of how much the preservationists could compromise before being compromised themselves. When it was all over, some believed that the preservationists had given too much.[58] With the advantage of hindsight, we now know that, although the preservationists made many concessions, they also created tremendous public support for their cause. Consequently, it has been possible to preserve the integrity of the wilderness system and enlarge it despite seemingly disabling provisions in the act.[59] As a soap opera character might say, since the preservationists and their public only accepted violation of their principles under duress, they were never really violated.

Grazing

Grazing is the oldest and best established commercial use of national forest wilderness areas. Until the 1920's, grazing fees were the biggest source of income from all national forest system lands, even exceeding those from timber harvesting. Stockmen were a potent political force in the west and exerted that power whenever the Forest Service threatened to raise grazing fees, cut back on overgrazing, or in other ways do something they did not like. Under these circumstances, the Forest Service had allowed controlled grazing in wilderness areas under the L-20 and U-Regulations.

In his 1949 report to the Library of Congress, Zahniser called grazing a "nonconforming" use which should be terminated. In 1956 he incorporated this language in the wilderness bill with the proviso that terminations be made equitably. In 1957, "nonconforming" was dropped. The bill provided that grazing "may" continue under such "restrictions" as the Secretary of Agriculture deems desirable. In 1963 the "may" was changed to "shall" and "restrictions" to "regulations."[60]

Some stockmen continued to oppose the bill almost to the end, although their protests became a little less strident as the bill's language was modified. But even with grazing recognized as a valid use of national forest wilderness, they were aware that they would not have the money-saving advantages of roads and motorized equipment in their wilderness allotments. Moreover, they, like other commodity groups, had an amorphous fear of wilderness legislation--that somehow it contained a hidden gremlin or that

it could be used to expand the wilderness system. The following 1958 colloquy between Senator Richard Neuberger and George D. Zahn, representing the Washington State Cattlemen's Association, exemplifies that attitude:

> Senator Neuberger.... Mr. Zahn, I just want to read to you one sentence in the bill, because you particularly mentioned grazing because that is the interest of the Washington State Cattlemen's Association. One sentence in the bill reads as follows:
>
> Within national forest areas included in the wilderness system grazing of domestic livestock...may be permitted to continue subject to such restrictions as the Secretary of Agriculture deems desirable.
>
> Now, do you believe that that is substantial protection for the economic interest in which you are interested.
>
> Mr. Zahn. Senator Neuberger, I believe that it is no protection at all. The word 'may,' if it was 'shall,' it would be excellent, but the bill in other places says existing rights if any. I believe the whole tenor of the bill is a mandate to the administering agencies of the Federal domain to place wilderness use paramount above all others.
>
> Senator Neuberger. Let me ask you this: If the bill were revised to change 'may' to 'shall' in the provision, would your organization then support it?
>
> Mr. Zahn. They couldn't support the bill, Senator, because, first they are not sure the legislative approach is the answer to this thing,....[61]

A reading of the statements of the bill's sponsors, drafters, and supporters over the years yields the following four general conclusions about the intent of the language on grazing in the Wilderness Act: (1) Grazing is a permanent legitimate use of national forest wilderness; (2) the drafters, however, intended to freeze the status quo in wilderness grazing. For instance, grazing cannot be introduced into a wilderness area that has not previously known it. The Forest Service can promulgate reasonable grazing regulations, as it does in other national forest areas. It can reduce stocking in areas that it finds to be overgrazed; (3) graziers do not acquire "vested rights" in their permits. Grazing in wilderness areas is a "privilege" just as it is elsewhere in the national forests; (4) structures and improvements used for grazing can be maintained but new ones cannot be built unless they are needed to help protect the wilderness environment,. e.g. drift fences.[62]

Motorboats and Aircraft

Motorboating and landing of aircraft were initially considered as nonconforming uses, along with grazing. They too became recognized uses but the political power of these users was apparently not as great as the stockmen because their "may" was not changed to "shall" nor their "restrictions" to "regulations." Presumably this difference in language means that while the Secretary of Agriculture can regulate established wilderness grazing but not abolish it, he could ban the use of motorboats or aircraft if circumstances seemed to warrant such action.[63]

Reservoirs

Water is a precious resource in most of the West. Many national forests owe their existence to pressure from western farmers and urbanites who wanted to protect their watersheds from damage by overgrazing or excesssive timber cutting. Zahniser was undoubtedly deferring to that fact when he proclaimed watershed protection as the dominant use of wilderness. But protecting a watershed and engineering it so that it will yield more water in the right ways are different matters. The first can be accomplished merely be leaving it alone, while the second often requires the construction of large-scale waterworks and reservoirs. Public support for a wilderness bill was aroused by just such a proposed project in the Dinosaur National Monument. Not surprisingly then, reservoirs were prohibited in the first wilderness bill. However, it soon became clear to the bill's sponsors that the water issue might kill the bill. For instance, Senator Thomas Kuchel of California, who was a co-sponsor of the first bill, dropped out in the next round because of his concern over Californians' need for water.[64] This problem was largely solved in 1957 when Zahniser accepted the Forest Service's suggeston that the President be allowed to authorize such projects, including the building of roads and transmission lines, when he deemed it in the national interest.[65]

Timber Harvesting

A wilderness bill that allowed timber harvesting would have been no wilderness bill at all for it would have licensed the largest possible alteration of wilderness environments. Some primitive areas had been partially harvested under the L-20 Regulations but commercial timbering was completely prohibited under U-Regulations and the Wilderness Act, except that wilderness miners could cut timber for their operations if it were not otherwise available and if the cutting were done under good forest management practices defined under national forest rules and regulations.[66]

Mining

In 1949 the Forest Service stated that mining, along with reservoir construction, was the biggest potential threat to its wilderness areas. Miners, like the stockmen, felt they had a right to wilderness areas even if they, unlike the stockmen, had made very little use of them. Under the Mining Act of 1872 and the Mineral Leasing Act of 1920 mining and energy concerns were given wide freedom to explore, stake claims, and apply for leases on the public domain. Timber companies may have resented the possibility of their exclusion from wilderness areas but they did not have such precedents on which to build a case. The miners felt that to exclude them would be flouting an American legal tradition and would damage the national interest by restricting the extraction of important metals.

As previously stated, Zahniser had prohibited mining in the first wilderness bill after at first allowing it when the President deemed it necessary for the national defense. At the urging of the Forest Service, a provision allowing mining when the President found it to be in the national interest was added in 1958 and remained in all of the important Senate bills. But the mining interests were not placated. They knew it would be more difficult for one of their number to get such permission than it would be for a city or community of farmers to get permission for a reservoir. Senator Gordon Allott of Colorado voiced their complaint in 1961:

> Let us take the case of a man who thinks he has found beryllium in a Western State. The bill provides that he must get the consent of the President to mine it. Beryllium is one of the new ores...It is only one of many. Yet, how would an individual miner ever get to the President of the United States to get the President's permission to go in and prospect or mine it? The answer is that this is just another piece of sugar held out to make people believe that we are not going to suffer under the bill.[67]

For the next three years the bill was stalled in the House Committee on and Interior Insular Affairs as its Chairman, Wayne Aspinall, maneuvered to incorporate affirmative action and the continuation of mining. The Senate was finally forced to accept the House Committee's provision that National t Foreswilderness areas be open to the mining and leasing laws until January 1, 1984. That was a bitter pill for the preservationists to swallow but the following comments from the Senate leader of the bill, Clinton Anderson, that show the language of the mining provision was subject to considerable qualification:

> I was asked by one of the Members of the Senate about the destruction of wilderness areas during the 19 years that mining laws are to be applicable, and about the language in the House amendment in that respect. I assured the Senator that I shared his concern. I feared that the language of the amendment might be misinterpreted to mean that mechanized equipment could be used

in prospecting--that bulldozers might be used to prospect or even cut long roads to the prospect areas.

We were assured by the House conferees that the House language has no such meaning.

We were told that the Forest Service has managed to avoid serious damage to the primitive, wild, and wilderness areas for 25 years or more; that Forest Service regulations governing mining activities in the areas can be continued and, indeed, that the regulations can be strengthened. The bill provides that activities in the areas shall be in harmony with the wilderness concept under reasonable regulations.

This was a crucial question in regard to the bill....

If there were to be a relaxation of mining regulations, which would permit serious depreciation of wilderness values, I would have sought to still be in conference.[68]

The Wilderness Act was passed as a result of many compromises, most of which were made by the preservationists. After it was over, some wondered if the campaign for the Wilderness Act had been worth the effort. It is true that the preservationists conceded several important points in order to placate other interest groups and to get the bill out of congressional committees. On the other hand, they created a strong popular movement which has been able to vitiate some of what they perceived as "disabling" provisions in the Act (witness the recent House Appropriations Committee ban on oil and gas leasing in wilderness). Even more importantly, they were able to take language allowing the President to recommend "contiguous areas" as wilderness, which may have seemed fairly innocuous to development interests in 1964, and use it to expand the wilderness system beyond the limits of the old primitive and wilderness areas and beyond the fondest dreams of its founders.

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E XIT RANCH: A BRITISH AGRICULTURAL EXPERIMENT STATION ON THE NORTHERN HIGH PLAINS OF TEXAS

by

WILLIAM M. HOLMES

At the Texas Constitutional Convention held in Austin in 1875, a resolution was offered requesting that 5,000,000 acres of the public domain be set aside for the purpose of constructing a new state capitol building. After considerable debate this amount was amended to 3,000,000 acres. The constitution was ratified in February 1876, but it was not until February 10, 1879 that a law was passed which provided for the extraction and survey of 3,050,000 acres from the original Capitol Reservation lands located in northwest Texas. The additional 50,000 acres were included to help defray the cost of surveying.

On November 9, 1881, the old capitol building burned and bids were let for the construction of the new building on January 1, 1882. The winning bid was submitted by Mattheas Schnell of Rock Island, Illinois who assigned three-fourths interest to Taylor, Babcock and Company, a Chicago dry goods firm consisting of Colonel A. C. Babcock, Colonel Abner Taylor, John V. Farwell, and Charles B. Farwell. A short railroad was constructed from Burnett to Austin and engineers familiar with granite quarrying were imported from Scotland. The cornerstone was laid in 1884 and the building was completed in 1888. Meanwhile, from the day the first ground was broken on February 1, 1882, title to portions of the Capitol Reservation was periodically transferred to the new owners as work progressed on the building even though permission had been granted by the state for the development of the entire 3,000,000 acres.

In March 1882, Colonel Babcock, along with a party of ten men including surveyors and a cook, set out to inspect the land the company was to receive. In his report, which was issued in the form of a prospectus, he observed that the plentiful grama, buffalo, and mesquite grasses made excellent forage for the buffalo, antelope, mustangs, and wild cattle which already occupied the land. In addition, he commented that "they also provided excellent cover for prairie chickens and tinder for prairie fires."[1] He further stated,

> Our lands examined by me are generally well adapted to agriculture. There is no question but that they will produce fine crops of all kinds of grain adapted to that climate. I found our lands and the climate admirably adapted for grazing purposes, the prevailing grass being mesquite, which is exceedingly nutritious, said not to be excelled in fat producing qualities. Stock require no other feed winter or summer.[2]

Some consideration was given to the immediate sale and colonization of the land but this was regarded as being impractical because of the absence of railroads. Consequently, the shareholders elected to follow Babcock's suggestion and develop a full-fledged ranching operation in an effort to realize some return for their investment until such time that it became economically feasible to sell land in smaller plots to farmers and stockmen.

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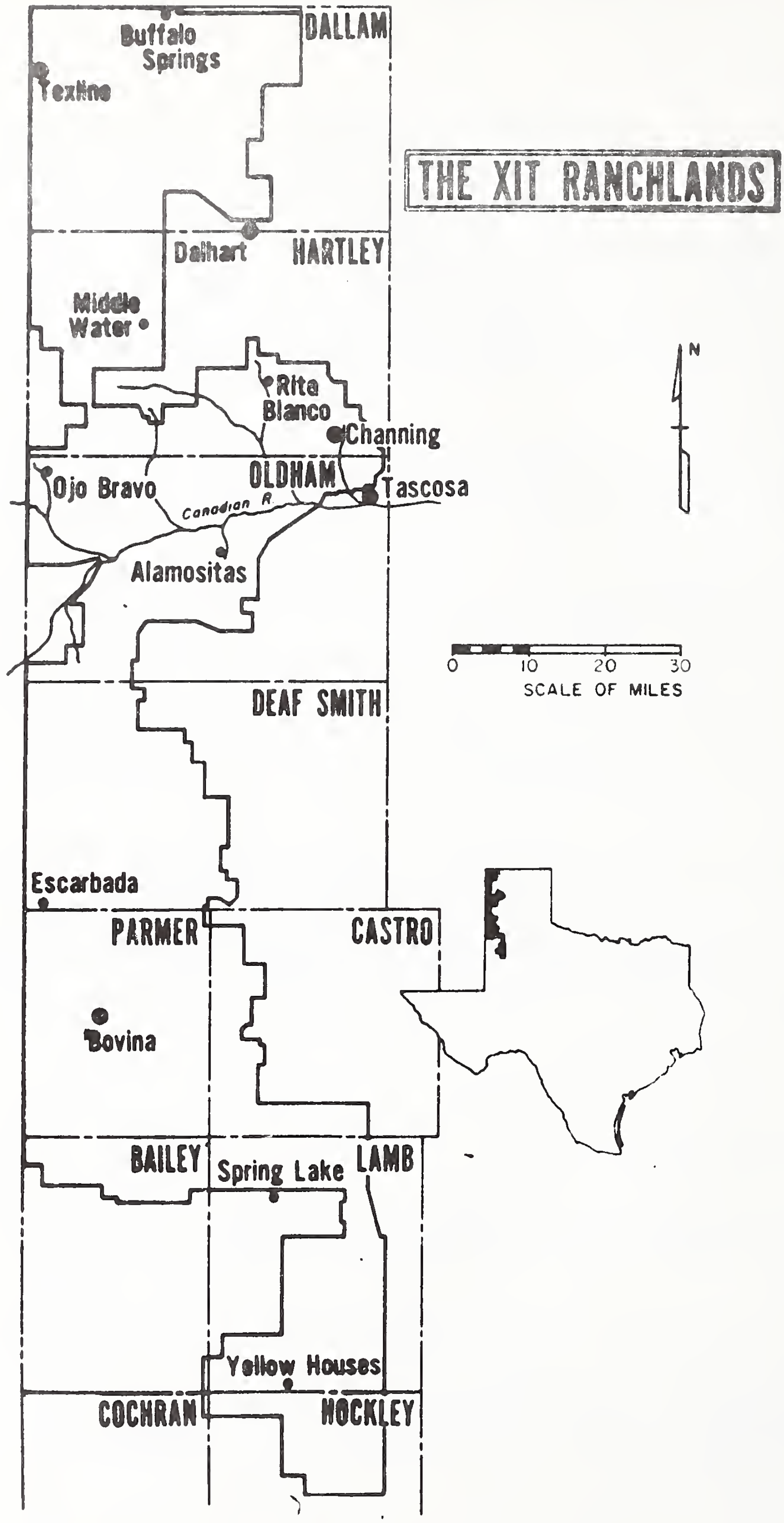
THE XIT RANCHLANDS
DALLAM
Buffalo Springs
Texline
Dalhart
HARTLEY
Middle Water
Rita Blanco
Channing
OLDHAM
Ojo Bravo
Tascosa
Canadian R.
Alamositas
0
10
20
30
SCALE OF MILES
N
DEAF SMITH
Escarbada
PARMER
CASTRO
Bovina
BAILEY
Spring Lake
LAMB
Yellow Houses
COCHRAN
HOCKLEY

Furthermore, since the "Cattle Boom" period of the 1880's was well underway and foreign investors were eager to purchase western range lands, it was expedient for the company to secure financial assistance from abroad for the purpose of developing the ranch as thoroughly as possible. Finding British investors was no problem and, in 1885, the Capitol Freehold Land and Investment Company, Limited, was finally organized. Headquartered in London, the company had financial backing of about $15,000,000 with which to properly equip and stock the ranch.[3]

Before investing in the enterprise, however, one English nobleman visited the land in 1884. He later wrote that the agricultural potential of the land was excellent, that the grazing possibilities were unsurpassed, and that the land was so flat that he "could start a plow point into the soil at the south line and turn a furrow two hundred miles without a break."[4] He also suggested the importance of analyzing the soils of selected agricultural sites and felt that each division of the ranch should maintain a garden, plant an orchard, and attempt some crops in an effort to approach self-sufficiency as far as supplying food for ranch hands was concerned.

It is apparent that most British investment was devoted to the range cattle industry and it is important to note that many companies lost heavily during the early 1880's and often sought to recoup some of their losses by becoming dispensers of land. As far as the Capitol Syndicate was concerned, however, livestock grazing was simply a use to which the land could be put until conditions favoring land sales improved. Although this paper deals with the XIT Ranch and the development of its agricultural experiment stations, other activity illustrating the versatility of British involvement in Great Plains agriculture during the period 1870-1910 are as follows:

(1) Encouragement of railroad construction;

(2) Advertising of western lands for sale in eastern and midwestern newspapers;

(3) Sale of land to Polish settlers by the Francklyn Land and Cattle Company;

(4) Sale of land to Russian-Germans in Lipscomb County by the New York and Texas Land Company;

(5) Establishment of towns such as Bovina and Channing which served as rural markets and distribution centers, and

(6) Involvement in western and midwestern farm mortgage companies.

In an effort to make some comparisons it is pertinent to mention some dates important to the development of American agriculture. In 1857, the Morrill Act, which provided for the establishment of Land Grant Colleges, was passed by Congress but was vetoed by President Buchanan. During President Lincoln's administration, however, the Morrill Act was passed and signed

into law in addition to a law providing for the establishment of a commissioner of agriculture. In 1887, the Hatch Bill was passed and in 1889 the Commissioner of Agriculture was made Secretary. The Hatch Bill, in addition to providing for the establishment of agricultural experiment stations in conjunction with the land grant colleges, established the framework for a uniform method of tabulating results of investigation and provided for the publishing of findings and making such publications available to farmers. It was not until 1897 that E. C. Chilcott started the first Great Plains dry-land experiment station at Brookings, South Dakota. This station was followed in 1901 by the Fort Hays, Kansas station and, in 1904, by the Amarillo station. These dates are utilized to make the point that the XIT Ranch had seven well organized agricultural experiment stations before the Hatch Act was passed. In order to more thoroughly understand how this came about a brief examination of the organization of the Capitol Syndicate holdings seems important.

At the head of the company was the Board of Directors which consisted of the principal American and British stockholders. Since the British were responsible for supplying the bulk of the financial backing for the company, the annual meetings were held in London until 1909 when the foreign company went out of existence. John Farwell was made managing director and was the mediary between the Board of Directors and the actual operation of the ranch. In addition to numerous other duties, he was responsible for submitting an annual report to the Board of Directors.[5] Immediately under Mr. Farwell was the General Manager of the ranch whose responsibility was to keep the ranch running smoothly. His office was at the main ranch headquarters, which were initially at Buffalo Springs, relocated to Alamocitas, and eventually moved to Channing.

The ranch was partitioned into seven divisions, each consisting of between 420,000 and 470,000 acres. These divisions were named and numbered as follows: (1) Buffalo Springs, (2) Middle Water, (3) Ojo Bravo, (4) Rita Blanco, (5) Escarbada, (6) Spring Lake, and (7) Las Casas Amarillas (Yellow Houses). The four northern divisions were supplied from Trinidad, Colorado until the railroad reached Channing and the southern divisions received their supplies from Colorado City, Texas until Amarillo ultimately became a railroad center.[6] Each division had a division foreman who hired and fired his own employees. Each division was operated as an individual ranch although some had, in addition, such individual specialties as breeding, culling, acclimatizing, and the bull division. Each division had its own constantly operating freight system, each kept its own books, and each had a division foreman who was obligated to submit a monthly report and an annual summary to the general manager who, in turn, reported to Mr. Farwell. Each division took care of its own fences, wells, buildings, purchase of supplies and implements, and submitted a periodic inventory.

In 1884, it was suggested that each foreman assume the responsibility of analyzing the soils near the division headquarters for the purpose of assessing the potential for agriculture. The quality of these reports ranged from fair to poor depending upon the expertise of the individual foreman who, in all likelihood, was not too skilled when it came to soil analysis. The foreman at Ojo Bravo, however, observed that its soils, "consisted generally of a deep loamy material of river deposits occasionally frequented with limy rock and infertile red beds."[7]

The Buffalo Springs' soils were considered a "sandy to sandy loam" while Yellow Houses' soils were regarded as loamy, but with "considerably clay lime within a few inches of the surface." The foreman at Spring Lake simply stated that the soils there were bound to be capable of producing grain crops because of "the fine quality grasses which grow."[8] In addition, the guidelines for the monthly report included daily temperature, precipitation, unusual weather phenomena, insect pestilence, prairie fires, number of acres cultivated, types of crops planted, crop yield when harvested, estimated value of crops harvested, and an assessment of the condition of animals and implements.

The initial attempt at experimentation occurred in the spring of 1885 when a "small tract" was broken at Buffalo Springs. Although it was planted late a fair crop of millet and corn was reported.[9] The Buffalo Springs farm was enlarged to 200 acres in 1886, 35 of which were planted in alfalfa with the remainder in millet, sorghum, and Indian corn. In addition, 30 acres of millet were planted at Middle Water and, on August 6th and 7th, 70 acres of millet, sorghum, and corn were planted at Yellow Houses. In "just sixty days from the time of sowing," the report states, "we gathered as fine a crop of millet as I ever saw growing in Illinois. Two weeks later we gathered a fair crop of sorghum and corn fodder." In the late summer, 100 acres were cultivated at Escarbada and planted during September with rye and millet in an effort to determine if either crop could be utilized as winter pasture. An undetermined amount of acreage was also broken in the late summer at Alamositos, Ojo Bravo, Spring Lake, and Rita Blanco to be planted the following spring. All were designated as dry-land experiment stations except in those instances where it was practical to irrigate small vegetable plots or gardens. In his annual report of 1886, Mr. Campbell stated that, "there is no doubt but that our lands are capable of producing a great variety of agricultural products." In addition, 5,000 trees were planted in a shelter belt experiment at Buffalo Springs and Middle Water. Although numerous species were attempted, catalpa and white ash were regarded as possessing the best survival rates.[10]

By 1887, the various experimental farms of the XIT Ranch consisted of more than 800 acres of producing agricultural land planted in an amazing variety of crops ranging from small patches of cotton experiments in the southern divisions to larger plots of numerous imported varieties of wheat from Russia, Turkey, and Italy in the northern divisions. All sorts of vegetables were attempted on garden plots at the various division headquarters and experimental orchards of apples, cherries, plums, and peaches were planted at Buffalo Springs, Escarbada, and Spring Lake.[11] The November 12, 1887, issue of the Tascosa Pioneer pointed out that the yield of a two-acre garden at Buffalo Springs consisted of 4,500 cabbages, 30 bushels of onions, 50 bushels of beets, and three barrels of pickles in addition to other vegetables. As an advertising scheme the Capitol Syndicate sent an exhibit of grains and vegetables to the Dallas Fair which resulted in a large number of inquiries as to whether land could be purchased. A. L. Matlock, in a letter written in response to an inquiry made by the editor of the Fort Worth Gazette, remarked that cabbage, cucumbers, beans, beets, onions, melons, squash, turnips, parsnips, carrots, radish, cauliflower, lettuce, and tomatoes had been successfully raised at Buffalo Springs that summer.[12] In his annual report of 1887, Mr. Farwell stated:

> We have been very much encouraged during the past year by the success of our agricultural operations. We think that a liberal line of policy in developing these possibilities, executed with intelligent operation and patient industry, will, without a doubt, yield large returns. About four-fifths of the entire tract seems eminently suited for agricultural purposes.[13]

The cotton crop of 1887 left something to be desired but the Russian wheat experiment of Buffalo Springs resulted in a yield of more than 20 bushels to the acre even though precipitation through October amounted to less than 15 inches. Alfalfa, oats, millet, sorghum, and corn were reported as having been very successful in spite of the shortage of rainfall.

The report to London in 1888 continued to support the production of grains but Farwell was especially enthusiastic about the "fine cotton crop that was raised on the Escarbada." The Escarbada division, located in Deaf Smith County had demonstrated by 1888 that its agricultural potential exceeded that of other divisions. Colonel A. G. Boyce, the general manager of the ranch, wrote in his annual report of 1888 not only that our "finest crops have been raised at Escarbada," but also "I wish to call to your attention the fact that this farm is situated on high plains land." He regarded these uplands as being far superior to "valley" lands to which the immigrant farmer is initially attracted. "The upland farm," he stated, "will sell for from three to five dollars an acre more than the valley lands." He considered the uplands more free from frost and more resistant to drought. He also observed that plains' agriculture was fully as successful as agricultural operations he had remembered in Travis and Williamson Counties some 20 years earlier.[15]

By 1890, more than 1,000 acres were under cultivation on the Syndicate lands with several experiments being aimed toward determining nutritional and storage capabilities of the various types of wild grasses which had been

cut for hay. Of the crops wheat, rye, oats, barley, and sorghum were receiving special attention since einkorn, emmer, and spelt experiments of 1889 apparently did not meet with a great deal of success. As a result of a very successful sorghum crop in 1890, John Farwell reviewed the progress of the sorghum sugar industry in Kansas for which there had been some support from the federal government. Experiments continued toward the improvement of sorghum with the desire that a sugar industry could become a reality; the annual report of 1892, however, revealed that

> Our expectations for the industry, for which our lands are suitable, particularly for Sorghum, have been modified by the McKinley Bill, which scheduled sugar on the free list, and nullified the bounty on its production of two cents per pound, leaving this infant industry where it was before the bounty was given.[16]

Although sorghum experiments continued, emphasis on its production declined in the years following 1892.

In the fall of 1892, a severe drought began on the Great Plains that did not let up until the winter of 1894-95. The Rita Blanco division, for example, received 25.66 inches of precipitation in 1891, only 6.91 inches in 1892, and conditions were so dry in 1893 and 1894 that no records were kept and no crops were successful. The division manager reported an infestation of Rocky Mountain locusts or grasshoppers during the dry years which consumed some crops and, much to his distress, one 40 acre field of volunteer oats that the grasshoppers missed was burned in a prairie fire. In addition to climatic problems, the country was in the throes of an economic depression, the combination resulting in considerable emigration of farmers from many portions of the Great Plains.

Although the report of 1892 dealt largely with cattle, the California industries of grape and prune production received considerable attention. The planting of vineyards was not attempted on a large scale "but enough experimenting has been done to prove that grapes can be raised in great perfection." Soils of the XIT were considered ideal for grapes but, since the winters were much colder than they were in southern California, the vines were protected by "earthing" them. The mission and wine grapes were successful but the raisin grape was considered ideal because of the perfect atmosphere for drying the fruit at the time of ripening.

Prunes, likewise, were not planted on a large scale "but those planted showed a vigorous growth and were well fruited." The trees were planted eighteen feet apart, which gives one hundred and thirty-four to the acre." Each tree yielded "two dollars worth of fruit or two hundred and sixty-eight dollars." They began to fruit after three years and were generally free from blemishes and insects. The region was also regarded as being ideal for prunes because of the drying capability of the atmosphere.

The report of 1892 closed with the following statement:

> Of course, you understand that all of our experiments in raising sorghum, beets, wheat, etc., were undertaken with the view of demonstrating what our lands were capable of producing, and not with the idea of there being any profit in the experiment per se. The results of such experiments have been in the main satisfactory, and while our Company is equipped and manned for the cattle business, and not for farming, and thus not calculated to produce the same results that a practical farmer whose livelihood depends upon the outcome, would likely secure. Its experiments clearly showed to our mind that adaptability of our lands to diversified farming as well as stock raising.[16]

While the drought and depression were momentarily disastrous, it was recognized that every year could not be counted upon to reliably produce a crop because of the vagaries of nature. Therefore, in succeeding years, greater attention was paid to more careful tending of the soil. It became important to presume that every year would be a moisture deficient year and the experimental farms of the XIT turned more attention to the types of implements proven to be beneficial to the soil and those regarded as being compatible with the established techniques of dry-land agriculture. For the average farmer the expense of owning adequate farm machinery was often too great but for the XIT Ranch nothing was spared when it came to machinery. The 1886 inventory listed such implements as hay rakes, mowing machines, a corn sheller, a hay stacker, a corn planter, plows, cultivators, a toothed harrow, a disc harrow, a pulverizer, levelers, a check rower, and a roller.[17]

In addition a letter the following year from the Deere, Mansur and Company, Saint Louis, referred to an inquiry about such farm machinery as, "New Deal plow, Acme pulverizer, Chicago pulverizer, Smith mower, Moline broadcast seeder, Deere and Moline two-horse corn planter, drill attachments, check rowers, and sod cutters." It was further explained that the corn planters could be adapted to sorghum.[18] During the same year, 1887, Abner Taylor wrote to Dakota requesting information about steam plows, stating, "We are thinking of plowing a lot of land next spring and wish to do it by steam if we can find the plow that will do the work."[19] There is nothing to indicate that the plow was purchased at that time but a steam plow was in use by 1903.

Although many of the implements listed on the 1886 inventory were utilized following the drought of the early 1890's, acquisition of additional harrows, plows, seeders, and headers changed the pattern of their use. It had been determined earlier that the upland flats were more productive than valley or bottom lands and grasslands or sod lands were regarded as more desirable than lands covered with mesquite or yucca. During the years following 1894, therefore, virtually all experimentation was devoted to eliminating the mistakes that were experienced during the drought years.

Deeper ploughing to break up the hard pan layer was proven to be a successful technique. Frequent harrowing, with a toothed harrow which broke large clods, to control weeds and to create a dust mulch that retarded moisture

movement to the surface became an established practice. Crop rotation, improvement of fallowing patterns, and the continued search for crops that were more tolerant of drought conditions were emphasized.

Winter what superceded spring wheat with Russian and Turkish varieties being more successful.[20] Wheat was planted in the fall and normally harvested from May to late June depending upon the latitudinal position and altitude of the farm.[21] Although oats were originally a late summer crop the trend toward early spring planting had developed by 1898.[22] Sorghum and Kaffir corn, from the earliest experiments, were planted in May and June and usually harvested in October.[23] The Johnson grass experiments were begun in 1894 but did not become prominent until 1898 when 520 acres were planted. It was considered an excellent hay.[24] By 1900 the experimental farms of the XIT were producing crops on 1,650 acres whose value was estimated at nearly $20,000. Although Johnson grass was the leading crop planted, alfalfa, wheat, rye, millet, sorghum, barley, and Kaffir corn continued as major crops planted to demonstrate to prospective land buyers the potential of the region.[25]

Railroads were becoming more common in northwest Texas and, after the turn of the century, the XIT became a major land dispensing company. The Farm Land Development Company bought 50,000 acres of XIT land in Parmer County and continued the experimental farm near Bovina for demonstration purposes. They also obtained 100,000 acres at Middle Water that included the experimental farm.[26] Other purchases of Capitol Syndicate lands were made by the Soash Land Company of Iowa, the Western Land and Immigration Company of Chicago, and C. R. Tallmadge of Chicago. The Atchinson, Topeka, and Santa Fe Railroad Company, whose lines extended across XIT lands, secured permission to sell farm land to midwestern farmers. More than 1,000,000 acres were sold in 1901 and 1902 to developers and individuals and, by 1907, nearly 2,000,000 acres had been sold.[27] By 1910 most of the Capitol Syndicate land had been disposed of and the company no longer was actively involved in experimental agriculture but the findings determined by the hardy farmers of the XIT certainly played an important role in the development of early high plains agriculture.

Although the findings of the XIT experimental farms were neither published nor highly publicized for the general public, information was made available to those who purchased Syndicate lands. Immigrant farmers were made aware of implements that were best suited to plains agriculture, they were kept abreast of new crops that were compatible to the fickle environment of the high plains, and they were assisted in the marketing of farm products. It was to the advantage of the land company to help as much as possible because the successful immigrant farmer was evidence that the company was honest.

After 1895 land companies and railroads became the agents for advertising the results of the XIT experimental farms. Findings were published in popular magazines, eastern newspapers, and in countless bulletins and brochures proclaiming the lands of northwest Texas not only capable of producing a wide variety of crops but also of possessing pure air, pure water, and the perfect environment in which to free oneself from the malaria afflicted world.

Information was also disseminated to farmers through personal inspection. The Soash Company and the Santa Fe Railroad periodically brought prospective land buyers to the experimental farms so they could see the potential of the land. In 1904 the Santa Fe Railroad began what company officials called "one of the biggest land and colonization schemes in the history of western railroads."[28] The goal was to relocate 20,000 farmers in northwest Texas and the Pecos River Valley of New Mexico. Homeseeker excursions left Chicago and Galesburg on the first and third Tuesdays of each month for Dalhart where prospective land buyers would be taken to see, first hand, the results of the XIT experimental farms. It is estimated that about 50 percent of these excursionists relocated in northwest Texas. This amounted to about 13,000 persons.[29]

In summary, the XIT Ranch, largely through British interest and investment, became the site of the first dry-land experiment stations on the Great Plains. The results of their experiments were made available to immigrant farmers, making it possible for them to take advantage of the findings of their predecessors thereby eliminating much of the expensive and exasperating process of trial and error. Today the search continues for more drought resistant crops, more efficient implements, and better techniques for conserving soil moisture in the marginal agricultural lands of the southern Great Plains but much of the formative work was done by the inquisitive cultivators of the XIT Ranch.

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THE UTILITY OF PLANT EXPLORATION

by

JACK R. HARLAN

The utility of plant introduction should be obvious to all. The chances are overwhelming that neither you nor I would be alive if plants had not been introduced into the United States. American agriculture is an imported agriculture. Even those native Indian staples, corn, beans, and squash were imported in pre-Columbian times from Mexico and the Caribbean Islands. Without plant introduction, there would be no agriculture in the United States as we know it. Sunflower, sunchoke, pecan, black walnut, cranberry, some American grapes, octoploid strawberries (in part), a race of hops, and a few other minor nuts and fruits constitute the food plant contribution of the United States. It would not be enough to support 200 million people. If it is useful to feed the population, then plant introduction is useful.

Plants, however, may be introduced without organized plant exploration expeditions. One of the most common methods is for farmers to move into a new territory and bring their seeds and flocks with them. This is probably how the Mexican complex of American domesticates reached what is now the United States. Evidence indicates that agriculture came to Europe by farming people migrating out of the Near East across the Balkans and along the shores of the Mediterranean. The peopling of the Pacific Islands by Polynesians was accompanied by the introduction of useful plants throughout vast regions of the western Pacific. There is, in fact, abundant archaeological evidence for the movement of cultivated plants in prehistoric times.[1]

By "plant exploration" something more purposeful is implied. A search is made to acquire certain plants for specified purposes. So far as we now know, the first government sponsored plant exploration expedition in history was that sponsored by Queen Hatshepsut of Egypt about 1500 B.C. She had caused a very large temple to be constructed at Deir-el-Bahari near Thebes and wished to have incense trees growing on the terrace. Incense was not native to her capital so she had five ships outfitted and ordered the party to the Land of Punt. There, they dug up a number of trees, set them in large tubs, loaded them aboard, and brought them back to the temple. The trees flourished and grew very large.[2] Of course, the expedition brought back many other useful or curious items as well. Plant explorers tend to collect artifacts as well as plants.

Botantical gardens, or plant introduction stations, if you will, were established in ancient Assyria, in classical Greece, and in various places of the Roman Empire. Alexander the Great took botanists along on his campaign to India. General Chang K'ien is credited with the introduction of alfalfa and the grape into China following missions to the west for Emperor Wu in 128-126 B.C. Indeed, a long list of introductions is attributed to

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this plant explorer, but Laufer has shown that evidence is either missing or negative for the other plants.[3] Undoubtedly, there were many exploration missions through the centuries that went unrecorded.

Cultivated plants, and their associated weeds, are generally mobile and are carried where ever agricultural people go. That is how European style agriculture came to America. Most of the early settlers were farmers, or intended to be, and they brought their own seeds with them to practice their arts in the New World. Very often the seeds they brought were poorly adapted to the new situation and crop failures were common. The settlers responded in two important ways: first, they quickly learned to use what the Indians had already adapted to the land, and Indian corn became the chief cereal of the country, and still is; second, they began deliberately to seek out plants better suited to the new environment than those brought from Europe. The search for superior germplasm in colonial times was more vigorous and systematic than is usually recognized.

The American Philosophical Society of Philadelphia with Benjamin Franklin as its President, established a Committee on Husbandry and American Improvement in 1769 and did much to encourage introduction of useful plants to all the colonies. The Society received on October 19, 1770, "a catalogue of such foreign plants as are worthy of being encouraged in our American colonies for the purpose of medicine, agriculture, and commerce" by John Ellis. The list included, among many, the soybean--now our number two crop in farm value--together with a recipe for making soy sauce. An abstract was prepared and published in volume 1 of the Transactions of the Society 1769-71.

Also published in the preface to the first volume was the following philosophy and strategy for plant exploration and introduction that should be brought to current attention for historical reasons:

> The fruits, trees, plants, and grain, introduced by the new inhabitants, are mostly such as were cultivated in European countries from whence these inhabitants came. But the soil and climate of these countries being different from that of Europe, no wonder if many of them do not succeed here as well as in Europe.
>
> If we may trust to the report of the travellers, (a) this country, in the same degree of latitude, very nearly resembles China, or the tract of land that forms the eastern side of Asia, in soil, climate, temperature of the air, winds, weather, and many natural productions. And the same resemblance is remarkable between the western side of the old world and the western sides of our continents; (b) whereas the eastern and western sides of the same continent differ greatly.----
>
> Philadelphia lies in the 40th degree of north latitude, the very same as Pekin in China, and nearly the same with Madrid in Spain and that part of California of which Sir Francis Drake took possession. In Philadephia and Pekin, which lie on the same sides of the two

continents, namely the eastern, the winters are cold, and the summers are very warm. The same winds, in both places, produce the same effects.----But the case is different in Madrid and California, though these places agree with each other in almost every circumstance.

This resemblance is manifest not only in the weather and climate, but is also remarkable in the soil and natural produce. Tobacco, Phytolacca (a poke), the persimon tree, the mulberry tree, with several others are natives of China, they are also the natives of this part of America. Ginseng is gathered to the westward, of Pekin, and as far as we know, has not been found in any other parts of the world except within the same degrees of latitude in America. These observations give grounds to hope that, if proper enquiries were made, many more of the native plants of China, and very possibly the Tea, so much in use among us, and now become so necessary a part of our diet, might be found in America.

Such of the plants of China as have been introduced here, seem to agree with our soil and climate, and to thrive in a degree equal to our warmest expectations; witness the rice, the whisk and the Chinese vetch.* These may encourage us to try others.[4]

Here we see a well-reasoned plan and strategy. The extent of the correspondence of the flora (and fauna) between eastern Asia and eastern North America was not realized at the time and awaited further botanical exploration on both continents. Interest in the remarkable similarities has recently been renewed and an extended symposium on the subject is organized for this year at the Missouri Botanical Garden. As it turned out, the agriculture of the eastern United States did not become very Chinese in character despite similarities in environment and a considerable importation of materials from the orient. Rice did flourish in South Carolina and Georgia for a long time and later in Arkansas, Louisiana, Texas, and California, but the main crops of the eastern United States are American in origin, if not from the United States, e.g. corn; upland cotton; Sea Island cotton; tobacco; peanut; tomato; potato; sweet potato; beans; peppers, and so on.

Across the Atlantic, the Royal Society of Arts with Benjamin Franklin as a member, was also promoting the introduction of new plants to the colonies as well as awarding prizes and medals for successful enterprises.[5] A considerable effort went into the promotion of the silk and wine industries. Despite awards and contests neither flourished to the hoped for extent.[6] American species of grapes did better than imported wine grapes but the English, by and large, had to continue buying wines from Europe incurring a drain on the balance of payments.

The immigrants continued to pour in and the imported agriculture pushed steadily westward. As the colonials had predicted, the ecology of the interior of the continent was different from the seaboard and new sources

*Chinese vetch = soybean

were required to fit the conditions of the prairies, the plains, the intermountain valleys, the southwest, and finally, the west coast. Some of the new strains were brought by settlers and some were deliberately sought out by plant exploration. One of the triumphs of immigrant introduction was Turkey wheat introduced into Kansas by Mennonite refugees from Russia about 1873. By 1919, the cultivar occupied 99 percent of the hard red winter wheat area and 30 percent of the total wheat acreage of the United States. It was seeded on over 21 million acres, nearly twice that of any other cultivar and far more than any single variety occupied today.[7] The original import was highly variable and many named varieties were developed from it.

Basically the hard red winter wheat industry traces to this source today. More than that, Turkey was one of the parents of Norin 10, the source of the semi-dwarfing genes used in modern wheats around the world. The Japanese had obtained Turkey from the United States in 1892 and used it to develop a number of high-yielding varieties including Norin 10.[8]

Near the turn of this century, plant explorers were sent to target areas to collect materials that should be adapted to defined situations. As agriculture reached the Great Plains, it was clear that new and hardier materials were needed. The first officially designated plant explorer was E. N. Hansen who was sent to Siberia in 1898 to collect materials hardy enough for the Northern Great Plains. Descendents of some of his collections are still in use. M. A. Carleton was sent to Russia and Central Asia in 1901 and obtained, among many other items, Kubanka a durum wheat that set the standard in the durum wheat growing area for decades.[9] David Fairchild and Walter T. Swingle explored for materials to fit the desert Southwest and subtropical Florida. They brought back dates and figs and Egyptian cotton that evolved into the long staple Pima types.[10]

Because of the devastation caused by the boll weevil, G. N. Collins and C. B. Doyle were sent to Mexico in the winter of 1906-07. They introduced the Acala type which soon set the standard for upland cotton. Collins along with J. H. Kempton also collected maize extensively in Latin America. T. H. Kearney collected cotton and H. V. Harlan collected barley in Europe, North Africa, Ethiopia, and India. Dorsett and Morse spent 18 months in Japan, Northeastern China, and U.S.S.R. primarily for soybean collections.

Throughout these early exploration efforts, the emphasis was on adaptation. Explorers were sent to a targeted area overseas to find materials for a targeted area in the United States. The strategy was sound and paid off handsomely. After the massive collections of U.S.S.R. scientists led by N. I. Vavilov, we became aware of centers of diversity and, indeed, had collected in them long before the term was coined;[11] we found by experience, however, that adaptation was the key to the success of an accession. Good germplasm is where you find it and may have only the remotest relationship to a center of diversity.

In actual practice, we found our best oats came mostly from Latin America; our best western wheats came from Australia and those best suited to the northern wheat belt came from Canada. The mainstream of orange germplasm in the United States came from Brazil and the Azores while that of tomatoes and potatoes came from Europe. Pima cotton came from an Egyptian source and some of our best early imports of rice originated in Honduras and Madagascar. None of these sources, however, had much to do with a center of diversity or a center of origin.[12]

As American agriculture matured and special problems arose, however, the picture changed. Ethiopia is a center of diversity for barley, among a number of other crops. No Ethiopian barley has done very well in the United States. But, when barley yellow dwarf virus (BYDV) struck in the western United States, the only sources of resistance we could find were introductions from Ethiopia.[13] The Ethiopian barleys took on a new significance and a new value. The time is long past when a newly introduced accession is likely to compete very well with our best cultivars but new accessions are constantly needed to meet new situations.

The example of P.I. 178383 has often been cited but, since it provides a good lesson in plant exploration strategies, will be cited once more. This is a collection of common wheat that I made in Eastern Turkey in 1948. There were no roads to Colemerik in those days and I reached there partly by driving a four-wheel drive jeep over a camel track and partly by mule back. The collection turned out to be a terrible wheat. It lodged, was susceptible to leaf rust, had no winter hardiness, although it required vernalization. It was a hopelessly useless wheat but was dutifully conserved for some 15 years until stripe rust suddenly became epiphytotic. It was then discovered that P.I. 178383 had good resistance to four races of stripe rust, 35 races of common bunt, and 10 races of dwarf bunt plus good tolerance to flag smut and snow mold. The accession now appears in the ancestry of essentially all the wheats of the Pacific Northwest and a special expedition was recently conducted to the same part of Turkey to obtain more material.[14]

Here we have two good examples of the importance of centers of diversity despite lack of adaptation of the accessions. Many more cases could be cited;[15] it has become almost a general rule. Centers of diversity are good sources of genetic resistance to many diseases and pests, as well as of parasites and predators of damaging insects that might be used for integrated pest management. The materials more often than not are poorly adapted and must be modified by plant breeding before they can be used. Furthermore, we did not realize we needed these "useless" accessions until a disease or pest irrupted and caused extensive economic damage. We did not know we needed resistance to the spotted alfalfa aphid until the aphid was introduced and caused devastating damage in the 1950's. What will be the next devastating disease or insect pest? Will we have the germplasm on hand to meet the emergency? How can we tell if we do not know what the next emergency will be? How can we prepare for the unknown?

Two strategies are rather obvious: we should assemble large collections that rationally sample the total range of variation of a crop and its wild relatives and, since our crops are imported, we should study them abroad in order to identify diseases and pests and sources of resistance to them before the harmful agents are introduced. Plant quarantine services are certainly desirable and serve an important function in reducing the movement of diseases and pests but it is unrealistic to expect them to provide full protection. The volume of human traffic, especially by air, simply cannot be monitored to that extent nor can the cargoes shipped by sea. It would be prudent to assume that every disease and pest adapted to our crops and climate will someday, somehow arrive on the scene. If some of them do not, so much the better, but we have no way of knowing which ones will produce epiphytotics or epizootics when they do reach our land. We should be as well prepared as possible and this requires, as a minimum, an inventory of the hazards. Plant explorers of the future may consist of teams of entomologists, nematologists, plant pathologists, and geneticists sent abroad to gather materials and information for integrated pest control systems.

As our plant breeding programs have become more sophisticated, still more demands are placed on our collections. We have passed beyond adaptation and resistances to areas of quality or special purpose genotypes such as chemical nulls. We are all familiar with opaque-2 and the subsequent successful searches for accessions of other cereals with high lysine or other amino acids that may be deficient. Genes providing higher quality protein than "normal" have been found in maize, barley, wheat, sorghum, rice, and probably others.[16] High oil and better protein was transferred from wild to cultivated oats. Higher soluble-solids, mostly sugars, were transferred from green-fruited wild tomato to commercial types. Lower oil and higher protein are being bred into soybeans. Low gossypol lines have been developed in cotton and stronger lint has been transferred from lintless wild cottons.[17]

Work on chemical nulls in soybeans has been going on for some years in the Crop Evolution Laboratory at the University of Illinois. So far, five different compounds have been analyzed. Nulls have been identified in each case but they are not easy to find. The search requires great dedication and persistence. The compounds and frequencies of nulls are shown in Table 1.

Table 1. Frequencies of chemical nulls in soybean

Compound	No. accessions tested	No. Nulls	Ref.
Kunitz trypsin inhibitor	2,944	2	(9)
Lectin	2,784	18	(17)
Beta amylase	2,979	2	(10)
Lipoxygenase-1	5,904	2	(8)
Urease	ca 5,000*	4	--

*(work not completed)

At least some of the chemical compounds are economically important. A trypsin inhibitor prevents protein from being digested. Soybean meal must be heated to destroy the inhibitor. If soybeans could be grown that do not contain the inhibitor, the cost of processing would be substantially less. Lipoxygenase activity tends to cause oil to go rancid. Oil from beans without lipoxygenase would be more stable. Lectin is thought to have something to do with *Rhizobium* nodulation, but lines without lectin nodulate normally. The roles of beta amylase and urease are not understood. Soybean seeds have very little starch and no urea.

From an evolutionary point of view, the nulls are highly significant. In all five cases, null genotypes germinate, grow, nodulate, flower, and set seed normally. They can be identified only by chemical means. Nulls and normals are essentially identical in all respects except for the presence or absence of the compound in question. Yet, nulls are obviously rare genotypes. A full explanation is not yet available. Each of the compounds has some insecticidal activity and it may be that they had selective value at one time as plant protectants.

It should be obvious that studies of this type could not be conducted without large, reasonably complete, and comprehensive collections. Lipoxygenase-1 nulls occurred at the frequency of 0.03 percent. There would be no reasonable hope in finding them in a small collection. The search for chemical nulls is simply an example of the searches we will be conducting in the future. Our instrumentation and analytical techniques continue to improve and searches for useful "quality" genes will become more and more rewarding. This, however, can only be done if we have an adequate base collection as a resource.

The function and utility of plant exploration have evolved with time. During the settling of our country, the search was for something that would do better than what we had. New crops or new landraces were sought out that would have better agronomic fitness than materials available. Adaptation was the theme. As plant breeding programs matured, materials were improved to the point that new introductions had very little chance of competing with

our best productions. They became a reservoir of resources for special characteristics: disease resistance; resistance to pests; resistance to stress (cold, heat, drought, salt, metals, etc.); improved quality; new cytoplasms for sterility systems; genes to modify plant architecture; chemical nulls, and so on. Such resources are of very limited value unless the collections are fairly comprehensive.

As it stands, none of our collections is as complete or comprehensive as it should be. Some are very large. The world rice collection maintained at the International Rice Institute in the Philippines is in the 60,000 item range. The USDA small grains' collection is of similar size. Still, there are gaps in geographic, ecological, or taxonomic coverage. The most common gaps are in the wild relatives. Very often wild races and species constitute a pitiful handful of accessions, yet they have proven to be excellent sources of useful characteristics on many occasions. A systematic, rational, carefully designed assembly of the genetic resources of a group is a rare thing, indeed.

Concern has been repeatedly expressed over the loss of genetic diversity in developing countries. As the ancient traditional landraces are replaced by newly bred high-yielding varieties, the genetic base of a crop is restricted and invaluable germplasm often lost. The problem is very real and the concern has been translated into action at national and international levels. The state of California has even launched a program directed at collection and conservation of germplasm important to the state. Some private companies and foundations have taken some action to help conserve selected species or populations. Whether the activities collectively are in time or adequate remains to be seen.

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PLANT GERMPLASM RESOURCES

by

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Historical Resume: 1492-1898

I have not seen the menu for the buffet lunch we will be enjoying in a little more than an hour from now, but I would wager that most, if not all, items on that menu will be derived from plants and animals which were not to be found in what is now the United States when the colonists from Europe arrived some 375 years ago. Turkey would be the only exception as a meat source from domesticated animals. Corn, beans, and squash would be apparent exceptions but even these were introduced from south of our borders by Amerinds centuries before the European colonists arrived.

If we dine on sunflower seeds, Jerusalem artichoke, and fruits and nuts such as blueberry, cranberry, strawberry, black walnut, and pecan, then we will be enjoying plants native to the United States that were domesticated since 1492.

This country, which stands unchallenged as the greatest producer of food that the world has ever known, which exports the production from one acre in three, is dependent upon the rest of the world for its genetic resources (germplasm) of practically all of its domesticated plants and animals. That is why plant introduction activities, which started with the earliest European colonists, were formalized by Federal government action as early as 1819, and formed the initial core of the U.S. Department of Agriculture when the latter was founded in 1862. Following the creation of the Department of Agriculture, plant exploration activities increased. Collectors were sent to Europe and China in 1864, the latter for Chinese sorghums. Efforts up to 1898 brought introductions of the navel orange, flax, olive, persimmon, sorghum, wheats, and other cereals. Many introductions of temperate fruits were brought in from Europe. Finally, by 1898, the Department of Agriculture's activities and interests in the introduction of new plants had become so great that a new unit, the Section of Seed and Plant Introduction, was established. With a modest beginning and an allotment of $2,000, a foundation was laid for an increasing level of activity that has had a profound affect on American agriculture.

1898-1982

Since 1898, over 400,000 plant introductions have reached the hands of American scientists. More than 200 actual foreign explorations to centers of crop diversity have been undertaken. But numbers alone do not tell the story. Two years after the Section of Seed and Plant Introduction was created, the rediscovery of Mendel's Laws of Inheritance triggered the development of plant breeding as a science. This, in turn, gradually but dramatically, changed plant introduction objectives from transplanting crops from other parts of the world into United States agriculture to supplying sources of genes to meet crop breeding objectives.

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The next very important milestone was the passing of the Research and Marketing Act (PL 733) by the 80th Congress in 1946. This Act authorized funds to the States for cooperative research in which two or more State Agricultural Experiment Stations cooperated to meet common objectives. This "Regional Research Fund" was to be used only for cooperative regional projects recommended by a committee of nine persons, elected by and representing the Directors of the State Agricultural Experiment Stations, and approved by the Secretary of Agriculture. The same Act also authorized the appropriation of funds for use by the Department of Agriculture for cooperative research with the State Agricultural Experiment Stations. As a result of this act, the four Regional Plant Introduction Stations, the Interregional Potato Project (IR-1), and the National Seed Storage Laboratory were planned and implemented over the next decade as budgets could be increased to accommodate them.

Throughout the 1960's, budgets for plant germplasm remained level while the purchasing power of those budgets decreased. Then, in 1970, the Southern corn leaf blight epidemic struck. Our corn crop was genetically vulnerable to corn leaf blight because, among other things, a single source of cytoplasm had been utilized in developing a major portion of the corn hybrids. There suddenly appeared a new strain of the fungus pathogen well-adapted to that Texas cytoplasm; favorable weather conditions promoted its sweep over the corn crop. The yield of corn dropped an estimated 50 percent or more in some southern states and 15 percent nation-wide.

Thanks to good corn weather the following year (1971) and to heroic efforts by seedsmen, scientists, and farmers, the epidemic that year was mild. The scientific and public reaction to the corn blight epidemic was not so mild. There was real concern that such a disaster could happen in this the world's leading country in agriculture and agricultural science. The National Academy of Sciences responded to this concern and set up a Committee on Genetic Vulnerability of Major Crops to find the answer to the question, "How uniform genetically are other crops upon which the nation depends, and how vulnerable, therefore, are they to epidemics?" The Committee's answer was that most major crops are impressively uniform genetically and impressively vulnerable. The Committee's report was published in 1972 and crystallized a long-standing concern among germplasm biologists that the rescue, preservation, and use of genetic diversity of the world's crop plants and their wild relatives was being sadly neglected and rapidly eroded.

Since 1972, there has been a world-wide awakening to the fact that genetic resources are of at least equal importance to the three--soil, water, air--traditionally referred to in discussing "natural resources." In 1974, the International Board for Plant Genetic Resources (IBPGR) was established by the Consultative Group on International Agricultural Research (CGIAR). In the same year, the U.S. National Plant Germplasm Committee was

established and began conceptualizing and organizing a national effort involving the U.S. Department of Agriculture, the State Agricultural Experiment Stations, and commercial interests involved in crop improvement and the seed trade. In 1975, the Secretary of Agriculture appointed the National Plant Genetic Resources Board (NPGRB). The NPGRB was a direct outgrowth of the alarm caused by the Southern corn leaf blight.

So we now have a National Plant Germplasm System (NPGS) that provides access to over 400,000 accessions of seed and clonal germplasms. This represents a good start on acquiring and preserving the genetic diversity of economic plants and their wild relatives. The NPGS is pursuing an accelerating program to acquire, maintain, and evaluate for use as wide as possible a range of genetic diversity of these plants before it is lost forever because of man's adverse impacts on natural environments and changes being made in agricultural patterns and practices. Plant germplasm has caught the attention of agricultural administrators and national legislators. Now we need to take full advantage of better budgets and do the best possible job in plant germplasm conservation and use.

The National Plant Germplasm System

The NPGS is designed to provide, on a continuing long-term basis, the plant genetic diversity needed by farmers and public and private plant scientists to improve productivity of crops and minimize the vulnerability of those crops to biological and environmental stresses. Genetic vulnerability of crops comes into play when an out-of-the-ordinary range of stresses from diseases, insects, drought, or temperature extremes exceeds the crop's range of tolerance or resistance to such factors. The results can vary from noticeable yield reduction in localized areas to disastrous crop failures over very large areas.

An NPGS objective is to broaden the genetic diversity of a crop throughout its production area by having that production come from an array of varieties, all productive but each different from the others in its range of tolerance to one or more potential stresses. This variety and range can reduce the likelihood of epidemic losses. The major activities of the NPGS are Acquisition, Maintenance, Evaluation, and Enhancement of Plant Germplasm; Research on Conservation of Genetic Diversity, Monitoring Genetic Vulnerability, and Information Management.

Plant Introduction

The Plant Introduction Office (PIO) is part of the Plant Genetics and Germplasm Institute (PGGI) of USDA/ARS at Beltsville, Maryland. It catalogs all incoming accessions, assigns plant inventory (P.I.) numbers, and distributes P.I. material to maintenance centers or curators according to established protocols and priorities. No collections are maintained by this office.

The four State/Federal Regional Plant Introduction Stations (RPIS) at Geneva, New York (NE-9), Experiment, Georgia (S-9), Ames, Iowa (NC-7), and Pullman, Washington (W-6), all have priority responsibility for maintaining primarily "wild type" and introduced germplasm of many selected crops. The crop responsibility lists may include not only crops maintained at the RPIS but also those under other curators at outlying locations in the region. Should any of the outlying collections come under any jeopardy, it is the responsibility of the Regional Coordinator at the RPIS to take steps that will assure their continued safe maintenance. The Coordinators (all are federal) have a national responsibility for each species assigned to them. Some of the major crop responsibilities of each station are as follows:

Northeastern Regional Plant Introduction Station, Geneva, New York - Perennial clover, onion, pea, broccoli, and timothy.

Southern Regional Plant Introduction Station, Experiment, Georgia - Cantaloupe, cowpea, millet, peanut, sorghum, and pepper.

North Central Regional Introduction Station, Ames, Iowa - Alfalfa, corn, sweet clover, beets, tomato, and cucumber.

Western Regional Plant Introduction Station, Pullman, Washington - Bean, cabbage, fescue, wheat, grasses, lentils, lettuce, safflower, and chickpeas.

The State Federal Interregional Potato Introduction Station (IR-1) at Sturgeon Bay, Wisconsin, focuses on potato variety development with strong emphasis on germplasm maintenance and upgrading to meet breeders' needs.

COLLECTIONS

The National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado, is a USDA/ARS facility and the nation's only long-term seed storage facility. The Laboratory maintains plant germplasm as a base collection for the United States and is a backup base collection for many crops in support of the global network of genetic resources centers.

The NSSL base collection is not intended to meet the day-to-day needs of plant breeders and other plant scientists but, rather, serves as a reserve stock to prevent loss of germplasm and erosion of genetic diversity. Generally, seed samples in the base collection are also held in a working collection outside the NSSL and, therefore, are distributed from the NSSL only when unavailable from another source. The primary objective of the National Clonal Repositories is to maintain and preserve valuable fruit, nut, and other selected crops which are normally propagated by vegetative means.

Twelve separate clonal repositories are planned. Five are now in operation:

Corvallis, Oregon - Pears, filberts, hazelnuts, small fruits, hops, and mint.

Davis, California - Grapes, stone fruits, and nuts.

Miami, Florida - Some subtropical and tropical fruits and sugarcane.

Indio, California - Date palm.

Mayaquez Institute of Tropical Agriculture (MITA), Mayaquez, Puerto Rico - Tropical fruits and industrial crops.

The USDA Small Grains Collection is located in the Plant Genetics and Germplasm Institute (PGGI) at Beltsville, Maryland. This working collection contains some 90,000 wheat, barley, oats, rice, rye, and Aegilops accessions. Annually, over 100,000 samples of these accessions are distributed in response to requests from all parts of the world.

INFORMATION SYSTEM

A feasibility study was conducted during 1976-77 which investigated and identified the need for information management systems in the efficient collection, conservation, distribution, and utilization of plant germplasm in the National Plant Germplasm System. Agricultural Research Service recognized the critical need for a nationally unified information system to serve the diverse needs of the NPGS. A cooperative agreement with the Laboratory for Information Science in Agriculture (LISA) to develop a computer-based information system led to formation of the Germplasm Resources Information Project (GRIP).

Analysis of the diverse needs of the NPGS community, its abundant information resources, and the necessary management and use of those resources led to identification of two basic groups of information users within the NPGS--those who supply and those who demand information. "Suppliers" are those who acquire, maintain, and distribute germplasm and data such as curators and staff of the NSSL and various plant introduction stations. The "demand" group is composed of those who use germplasm and data such as plant breeders, scientists, and researchers. The needs of both groups were identified and small-scale operational prototypes of the system were developed and installed at such NPGS sites as the Regional Plant Introduction Stations. Testing and evaluation of these prototypes (including consideration of user responses and suggestions) then led to the information system's user-oriented design.

Among the ways the Information System will serve the supply side will be by providing mechanisms or tools to register accessions as they enter the NPGS, maintain seed inventories, monitor viability of collections, process seed orders, exchange information with other "suppliers," and generate summary

reports. The system will allow the demand side to receive information on accessions (including characteristic data and use and location in the system) as well as requested samples on a timely basis. The now completed design phase and start of a four-phase implementation will bring the transformation of GRIP to GRIN--the Germplasm Resources Information Network--and continued growth of information management and use in the NPGS.

The Information Network will include not only computer hardware and software but also people performing specialized tasks, work procedures, and administrative and policy functions. GRIN has been designed to accommodate growth of the NPGS and changing needs brought about by that growth including additional Information System features and more NPGS facilities and users. This flexibility in fulfilling many critical needs is the key to GRIN's anticipated success and continued evolution.

ADVISORY GROUPS

The National Plant Genetic Resources Board (NPGRB) provides policy advice directly to the Secretary of Agriculture. The task of the Board is to advise the Secretary on problems, needs, and welfare of the nation's plant genetic resources activities as these impact on the food production system.

The National Plant Germplasm Committee (NPGC) was established on May 20, 1974, when the Agricultural Research Service (ARS) agreed to a restructuring of the National Coordinating Committee for New Crops, which had been created in 1949 by State Agricultural Experiment Station (SAES) directors. The functions of the NPGC are:

> Provide coordination for the research and service efforts of federal, state, and industry units engaged in the introduction, preservation, evaluation, and distribution of plant germplasm, through representation of all unit's views by Committee members;
>
> Develop policies for the conduct of the national plant germplasm program and for its relationships to international plant germplasm programs and recommend these to the NPGRB and agencies involved;
>
> Develop research and service proposals and justification for adequate funding of regional and national plant germplasm activities.

The NPGC forum will also be the principal way in which SAES interests can be presented and harmonized with federal interests at a technically informed level.

THE CROP ADVISORY COMMITTEES

These Committees represent the germplasm user community and provide guidance and coordination to the NPGS on a crop-by-crop basis. There are currently 13 Crop Advisory Committees which are composed of plant scientists drawn from the public sector, both the federal and the state, as well as from the private sector. The curator of each crop serves as a member on his specific crop's committee.

The Crop Advisory Committees have worked on problems regarding exchange of information and have developed minimum lists of descriptors to characterize each crop. They have also developed germplasm evaluation plans. Other pertinent issues addressed by the Committees are:

Germplasm acquisition strategies;

Working collection storage conditions;

Long-term storage conditions;

Regeneration;

Seed distribution guidelines;

Standards for germplasm evaluation.

COMMENTS

by

THOMAS D. ISERN

Dr. Harlan, writing as both a secondary compiler and a primary source (drawing on his own experience), gives an admirable, insider's interpretation of the history of plant exploration. His voice is that of the scientist concerned with history; mine is that of the historian interested in science. The juxtaposition of our two perspectives on an agreed topic, in this case plant exploration, seems to me to typify the intent of this conference.

As Dr. Harlan notes, plant introduction is ancient and pervasive, embracing both the transferral of plant material as part of the cultural baggage of immigrants and the conscious efforts of individuals, organizations, and governments to find and disseminate desirable plants. References to the agricultural concerns of the founding fathers and recognition of a degree of continuity between their efforts at plant introduction and those of the twentieth century are in order.

Yet clearly the heyday of plant exploration comes after the establishment in 1898 of the Section of Seed and Plant Importation under David Fairchild, son of the President of Kansas Agricultural College. I contend that in this turn-of-the-century era there was a change not only in volume of introduction but also in its theoretical and philosophical underpinning.

First, recognize that before the 1890's we hardly may say that there were such creatures as agricultural scientists in the United States. However acute their observations, men such as Franklin and Jefferson were laymen who dabbled in science. Contrast them with plant explorer Mark Carleton. A farm boy from Kansas, he took his degrees and did his early research in field botany prior to entering the fields of vegetable pathology and agronomy. That was the common pattern for agricultural scientists of his generation--training in pure science, then moving on to application.

Second, realize that this was the first generation of scholars A.D.--after Darwin. To be sure, Franklin speculated that the fauna of China would flourish in the eastern United States, but Carleton knew that hardy wheats to settle the American Plains would be found on the semiarid Russian steppes, and he knew why--that through natural selection, environment would have shaped them there. "I am more and more convinced," he wrote, "that the influence of soils and climate on the character of wheat varieties is a matter of the greatest moment to American agriculture."[1] This idea of environmental comparison as the basis for plant exploration, which Dr. Harlan terms "adaptation," reached its height in the environmental studies connected with date palm introduction conducted by Walter T. Swingle, the stuttering plant breeder from Kansas who was the premier intellectual force in the SPI.[2] Adaptation as a theme served plant exploration well, as Swingle proved with his date palms, Carleton with his wheats, Niels Hansen with his forage crops, Seaman Knapp with his short-grained rice, and Wilson Popenoe with his avocados.

Third, and more broadly yet, plant exploration at the turn of the century was clearly a manifestation of American progressivism. The progressive plant explorers were instrumentalists who smothered Malthusian doom-sayings with faith in science. They were utilitarian, meaning they applied their research to

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national problems, an attitude surviving to the present in Dr. Harlan's title, "The Uses of Plant Exploration." Not unlike the British mercantilists who sought new plant industries for their American colonies, they were nationalistic, sometimes arrogantly so, carrying off botanical treasures from peoples whom they held in contempt. Most of all, as progressives they pursued the public interest. Plant exploration was not for the benefit of farmers as an interest group, but for the general consuming public.

These progressive scientists were as ardent in the application of Mendel as of Darwin. Fairchild was a dreamer, the romantic whose vision set plant exploration in motion but his compatriot, Swingle, was an early convert to hybridization and the forger of the partnership between plant exploration and plant breeding. Hence the need for the accumulation of a gene pool, leading plant explorers to collect in centers of diversity, as Dr. Harlan explains. I suggest, however, that this trend among American plant explorers predated publicity of Russian experience. Even such a rank generalist as the eclectic Dutchman, Frank Meyer, one of the great explorers and adventurers of the twentieth century, knew this. He collected knowingly in far eastern centers of diversity and origin and predicted that geneticists would do things with his introductions that he did not even imagine. "In the future we will create unheard-of strains of fruits and shrubs and trees," he wrote to Fairchild. "We are only cutting out a few steps in the mountain of knowledge, and others have to mount by our steps."[3]

The progressives had their way. They established in the United States, regionally or nationally, whole new plant industries--fig, date, short-grain rice, durum wheat, hard winter wheat, upland cotton, soybeans, sorghum, and others. Before we total out the balance sheet on plant exploration, however, there are two other sets of figures to consider.

First, we cannot yet complete the catalog of benefits attributable to plant exploration. The introductions of Dr. Harlan, or of Frank Meyer for that matter, hold hidden genetic virtues of future value upon which we can only speculate.

Second, there are the environmental effects of plant introductions to consider. Certainly the farmstead where I grew up in western Kansas would have been less hospitable without the shade and windbreak of Chinese elm trees, which we owe to Frank Meyer, but not all effects have been so felicitous. That same farmstead in the 1930's choked under a cloud of blow dirt churned into the air by a chain of circumstances in which the introduction of Russian red wheats was a key link. And when on the same high plains environmental collapse comes, as it will, with the exhaustion of the Ogalalla aquifer, as well as with the depletion of shallow and surface water, shall we not see similar links in the introduction of sorghums and upland cottons?

Indeed, during the 1930's, urged on by Secretary of Agriculture Henry Wallace, the plant exploration program set out to bind some of the very wounds it had opened by launching the unfortunately ill-fated erosion expeditions, intended to discover grasses and ground covers to turn wheatlands on the plains back to grasslands.[4]

How can a rational program managed by public-spirited experts produce such hazardous by-products? One obvious answer is that government plant explorers have no control over public use of their introductions. Mark Carleton may have placed Russian wheats in the hands of plant breeders at the Kansas Agricultural Experiment Station, but it was not he who plowed under the grasslands of the southern high plains.

Another answer is that at least in the first three decades of the plant exploration program, explorers and administrators mused little on potential environmental effects of their introductions. Dr. Harlan's paper indicates that this may be different today, inasmuch as exploration proceeds in less direct fashion toward introduction. Yet the suspicion lingers that we have not entirely overcome biases like those of the progressive era, that we are more adept at bringing home simple plant material than at digesting its environmental and cultural implications from its original home.

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DATA BANKS: FUTURE DIRECTIONS AND PERSPECTIVES, A RESEARCH VIEW

by

MARTIN H. ROGOFF

Researchers are a group of people who by the nature of the market place in which they traffic their wares are quite sensitive to need. Depending on where one researches, the needs may relate to different sources; for example, in industry it is the corporate need or, more specifically, a marketing division need. For we who research in the Federal sector, it will be national need, or constituent need, or need of another Federal agency. And we, as researchers, are expected to respond to these needs at least insofar as we, in turn, hold an expectation that the checks will arrive every second Wednesday. This is just preamble to express to you my delight in having a chance to unburden some of our needs in the research sector of the community on another group that constructively seeks to meet them. What I will deal with here will also seek to find constructive means of expression of researchers' information needs, not in the vein of providing solutions but, better perhaps, in a vein of clarifying the research perspective on the mutual data problems we face. This will help us to interact to solve them from a more unified perspective. Hopefully, what I discuss here will not present an image of such enormous complexity that we will all just throw up our hands and limp along. The technical and information revolutions which are taking place now are inextricably interwoven. Unless complementarity between them is achieved, we could conceivably end up at cross purposes--an intolerable outcome.

I will not set out to define the universe. I'm going to approach this by discussing the five following subject areas:

1. The Research and Development Continuum;
2. Disciplinary Vertical Integration;
3. Core and Peripheral Interest Areas;
4. The Value of Negative Data, and
5. Key Word Systems.

The time limitation on this talk assures you that I can achieve no real depth of detail here, so I will simply seek to get the general flavor of the subject across to you for use in your own areas of activity. I will try to develop for each of the subject areas a decision criterion which relates to information systems meeting the particular need the subject area illustrates.

The first area relates to how research operates overall. We can assume that the bulk of research performed is research which addresses resolution of a known or articulated problem. There is really very little science carried out for the sake of science. Certainly, it would be no more than that which could be characterized as funded by universities utilizing university funds. This so-called free inquiry research probably accounts for less than ten

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percent of research performed. Do not confuse so-called basic research with free inquiry or science performed for the sake of science. Little, if any, publicly or industrially funded basic research is performed other than in areas for which it has been determined that fundamental knowledge generated would be potentially useful in the attainment of implicit or implied programmatic goals. In short, most of the research being carried out is done within a blanket concept that out of the science will eventually emerge a technological end product.

The Research and Development Continuum

Research knowledge generation and its use in research and development activities is carried out within a system often called the Research and Development Continuum. The most interesting thing about the system is that it is generally asystematic. Research does not need to be terribly orderly but it seems, at times, to be deliberately disorderly. The R and D continuum (Figure 1) is composed of four activity areas: Fundamental, Exploratory Research, Applied Research, and Development. Some prefer to view Development as two activities: Scaleup and Commercial Development. No matter. The fuel for the activities is dollars and knowledge, but they are independent functions. What is important in the context of today's subject is the knowledge flow in the continuum, translatable to information and data flow directions.

What must be understood is that the continuum must maintain a data flow in the direction of technology development or other use, and that gaps in the continuum must be avoided. It is the information scientist's role in the functioning of the continuum to assure that gaps do not develop as a result of information gaps. Seeking proper dissemination audiences for data must be an ongoing activity, reaching an operating goal. Data dissemination unless targeted, however generally, is simply leaving receipt of the data to chance.

There are several points relating to the Research and Development Continuum which are important for the information sector. These are:

1. Information flow in the continuum should be iterative since research is an iterative process. As higher stages of the continuum are reached, such as the development stage, new research needs are generated as new data gaps are uncovered. Within organizations, the iterative flow is simple. The larger the spectrum of activities covered, the more difficult it becomes to maintain.

2. The main initiation point of concern for research data to enter the continuum is at the fundamental as well as at the exploratory level. Some technology emerges from the exploratory to development path without recourse to the fundamental base other than cursory literature search at unit library level. Again, uncovering of data gaps may

stimulate fundamental work, but not always. In some industrial activities, such as screening, fundamental data may never be sought or emerge. In these instances, post facto linkage needs occur when fundamental knowledge is generated later. Unless these linkages are made, the wheel may be reinvented several times.

3. Although iterative systems are needed, the directional pressure of the information flow need not be equal. The stronger flow is generally from the fundamental and exploratory areas towards commercial development. The reverse flow, driven by recognized need for specific data, usually generates monetary resources for its performance. This information travels faster than most other kinds.

4. Data of any kind must be correctly identified as to Research and Development Continuum stage. This usually requires more than the researcher's opinion of it. Every piece of exploratory data that gets classified as development strains the system's credibility.

The decision criterion that is key in information transfer relative to the Research and Development Continuum is: <u>Assuming this data is correctly classified as to Research and Development Continuum stage, do the information channels proposed reach the correct set of recipients who can use it to perform the next stage of Research and Development activity?</u>

<u>Vertical Integration</u>

The nature of the operational process by which research is performed is basically disaggregative. By this, I mean that regardless of the scope of the research problem addressed, the actual performance of the work is broken down into the smallest work units possible at the bench.

In university research, problems are normally broken down into small pieces amenable to attack by an individual graduate student. In public sector laboratories, the problem is attacked at the individual scientist level, possibly expanded by the use of one or more technicians. In industrial laboratories, the same pattern is generally followed on a somewhat expanded individual base since analytical routine procedures and other service operations are usually provided for this individual researcher. An additional unit dimension may be added in interdisciplinary research which can aggregate the effort of several individual scientists into a team attack on a problem. The point is that descriptors of research at bench scientist level may not be very informative about the actual problem the research is attacking.

Now within the context of the research and development continuum it should become apparent that in dealing with any research problem of substance, the progress of individual or even small teams of scientists must be aggregated at some level to obtain the broadest possible benefit from the information.

As knowledge accumulates in a given area, the useful aggregation level is pushed higher and the receptive use scope for the data broadens.

As a hypothetical example in the area of biological control agents, if an agent for mosquito control were a stated need, the research might start with examination of a moribund larva by a graduate student in Insect Pathology which reveals a viral infection as the causative agent of death. The next step is examination of the viral host spectrum and involves testing at several laboratories which rear other insects where it is found lethal for several species of mosquitoes, blackflies, and gnats. Interested virologists obtain subcultures and find it related to other entomoviruses but with an unusual protein in the viral outer membrane. Immunologists now find the protein to elicit unusual immuno-chemical responses in tissue cultured cells intimating potential for stimulating immune response to cancer cells. Field entomologists test the virus and find it reasonably efficacious but short-lived in nature. Industry gets interested and turns loose microbiologists on production and formulation, field development people on efficacy data, and a host of scientists on human and ecological hazard potential evaluation. All elements must have all of the information to get the microbial agent into the field as useful technology. Meanwhile, back at the ranch the graduate student finds another virus, startlingly similar to but four times as lethal as the original isolate. The vertical integration chain for the second bit of data is drastically different from that of the initial discovery. But both pieces probably entered the literature of "Isolation of a Parvovirus From Culex pipiens." In short, what is happening then is that all information now generated is being integrated into research higher in the R and D continuum for some useful purpose. More than one vertical integration chain can arise in any research line.

For the information sector then, in dealing with an information element in what is a very dynamic system, the second criterion arises: Have the necessary integration channels been identified to assure that those whose current work might be impacted by the finding get the information?

Core and Periphery

One of the truisms in technology development today is that the basic scientific findings which lead to many developed technologies do not emerge within the industry or investigation area in which they are eventually used. This means that information from unrelated fields can be critical to operation of the Research and Development continuum. It also means that the base activities, the fundamental and exploratory research activities are larger areas, and more critical in terms of their need to be communicated, than we conceptualize traditionally. In short, although the concept of disciplinary relationships shaping communication channels is generally applicable, and a useful working model, it is not a useful description of the total system served. Its use can create gaps in the continuum, and there are many who believe that there is a serious gap today between the fundamental research activity and the rest of the continuum.

Restating this, it is a practical certainty that at the time at which a bit of research information is generated there is no telling precisely where its ultimate impact may lie. True that when a researcher has solved a problem which provides data whose lack constrained achievement of a specific research goal, he can within limits see a distance up the continuum as to where and how the data will impact. But there is little probability that any researcher can shout, "Eureka! I have counted the facets on the compound eye of a tsetse fly and this means that 12 years from now we will be able to photograph the surface of Alpha Centauri." It just doesn't work that way, and we are hard pressed to define the peripheral audience for information. How to define it is a problem which we must jointly address.

Another reason for addressing the problem is that information is a key element in fostering innovation and creativity in science. Creative thought is not derived from a vacuum, it derives from a data base. To get to the point of why "core" and "periphery" concepts are important, let me define innovation and creativity for you from a researcher's view. Both have to be defined because creativity is an element in innovation. For me, innovation is the end use of solutions to problems developed through a process involving creativity in science. I define creativity in science as a process of arriving at a significantly better solution to a problem than would have been arrived at by a well-trained scientist relying on conventional theory, conventional wisdom, and/or conventional technology. In short, use of unconventional data combinations is creative thought. The hypothesis that must follow is that the database from which creative science, hence innovation, arises cannot be the same as that from which conventional solutions to problems arise. This is not just an exercise in causist philosophy. We cannot all be creative; creative individuals are born, not made. Creative individuals operate in a different activity sphere and from a different database than do the non-creative people.

Taking into account my prior statement that there is a low likelihood that we can predict with any accuracy where disparate pieces of information will be put together to generate an innovative solution to a problem, it is difficult to state an information science role in increasing the frequency of innovative outcomes. So this criterion will have to be stated in negative terms. It would be: <u>Has the spectrum of audience for this piece of information been drawn so narrowly that it will constrain the probability of its creative use?</u> I raise the sin to the level of commission as opposed to omission to point out its importance.

The Value of Negative Data

It may be just a little unfair to raise this question in an information forum. This because I am not sure solutions lie with information dispersal people. It is, however, an information dispersion problem. The problem functions at several levels. First let me state it. Scientific data generated at the bench level may well be overwhelmingly negative. The phenomenon an experiment is designed to express or measure is not expressed under most of the experimental conditions which the experiment includes.

Let me give you one or two hypothetical examples before total confusion sets in. Let's say we are screening micro-organisms from soil to find one which can produce aspirin, acetyl salicylate, from phenol. We screen 12,000 bacteria in a year and find one culture that does it. Of the 12,000 we tested, 5,000 grew on the test plates, but only one produced the desired compound. This will probably enter the literature in a Materials and Methods Section of a journal as "A screening medium containing 0.1% phenol, Behnke's mineral salts mixture and ferric chloride which produces a purple color with acetyl salicylate was used to obtain the converting strain." The fact that 5,000 strains grew on phenol and were not inhibited or killed by the toxic phenol may be the most important data from the view of the broader scientific community. It will not enter the data banks yet neither will the fact that 20 strains produced compounds which formed a purple color with ferric chloride, but which was not due to acetyl salicylate.

Another example: A researcher needs a non-aqueous fluid to activate a pressure operated solenoid by expansion under rigorous space conditions. He finds the right mixture which has just the correct expansion coefficients. He applies for a patent and four years later publishes his data when the patent issues. The data on the 6,742 fluid combinations he tested which did not expand usefully and the one that contracted when it should have expanded never reach the data banks.

There are many reasons negative data seldom emerge. First of all, researchers have a pattern of taking off in their work from the positive findings of someone else. Second, lines of work yielding negative data are not pursued overly long because research is generally evaluated and funded on positive findings. Third, most researchers have been trained in the use of positive data but not in the use of negative data. Thus, the research thought process generates experimental designs which probe if X happens, it will show Z, not if X doesn't happen, it will show Z. Fourth, the logarithmic increase in journal publications has generated editorial policies which favor brevity and the publication of positive findings. I really hope I'm wrong but, intuitively, I would guess that ninety-five percent plus of all potentially useful research data has never entered the data bank and lies buried in a million laboratory notebooks.

I have no solution; I ask you to ponder on the question. You are in good company. Both Albert Szent-Gyorgi and Linus Pauling have given the matter serious thought. I can offer here only the weak information criterion: Have we thought about where the negative data in this data might be useful? There is a separate question relative to publication through in-house media of in-house negative data.

Key Word Systems

This last discussion area highlights what has to be a major point of frustration for researchers. This is the use of key word systems for data recovery. We have all been frustrated in using key words and not retrieving data which could have saved us time, effort, or embarrassment. We who

research all know the sinking sensation in the stomach in trying to respond to the first comment after the paper that starts, "I see you are unfamiliar with the work of . . . ."

The concept of retrieving data on the basis of key words relating the data to larger aggregations of work is sound and logical. But, in accordance with everything I've said in the preceding brief remarks, the successful use of such a system is a function of correctly identifying the potential audience. If any salient points emerge from my remarks, they are that the audience is in a dynamic state, it is constantly shifting, and it is never, ever, a single audience. There are always many potential audiences for any given piece of data.

So let me state the question we have to answer relating to the use of key word systems. It is: "Whose key words?" or from the diametric perspective, "Key words to whom?" Let's look at the system. As we do things now the main source for the key word designations is the generator of the data himself--the bench scientist. This source for key words provides a reasonable assurance that key word alignments along direct disciplinary lines, and even along related disciplinary lines, is probably correct. The bench researcher is sure of the spectrum of disciplinary sciences with which he interacts, the literature that he reads as well as the literature of his that is read. But if we look at key word potential use spectrums, how does the bench scientist fit in relation to some of the larger framework structures I have discussed here? How does his input relate to the research and development continuum, scientific vertical integration chains, or core and peripheral scientific and organizational activities? Going back to the example I used before of the graduate student isolating viruses from deceased larvae, we can ask the question, "With what certainty can we assure that the graduate student recognizes the different audiences for his new discovery of the more virulent strain than existed for his initial isolation?" We can assume recognition of some portion but not for all of it. My intuition tells me that "some" means a minor fraction of the potential audience.

Looking at this situation from a more parochial view, that of our own CRIS system and the uses to which it is put, I have to say that from a staffer's view, the system in key word terms often does not meet my needs. In the staff responsibility, for example, I have to deal with the data in crosscutting activities situations, potential for useful outcomes situations, impacts on activities, locations, legislation, appropriations, strategic planning or future development situations. In all of these the technical aspects are secondary. The primary thrusts are organizational for use of the data by staff. Yet, in staff terms, or in strategic planning terms, the data are difficult and sometimes impossible to retrieve on a key word basis.

So for key word retrieval, at least for in-house problems, we must think of scientific data less in terms of its scientific content and use and give some thought to its organizational use and the means of making the system more responsive on organizational criteria. Beyond in-house

considerations, key word systems should seek to identify newer sets of descriptors for relationship of bench outputs to broad problem areas, issues of natural concern, disciplinary interfaces at broad scientific levels of disciplinary aggregation, potential for crosscutting topic applications, and relatedness to potential use outcome forecasting.

Boiled down to key elements the criterion proposed for key word use becomes simple. It is: "In developing the key word system have we paid attention to the relation of this item to the R and D continuum, vertical integration, core and peripheral interest, the value of its negative data, and its organizational use potential in the organization in which it was generated?"

I will beg the question of precisely how we should go about accomplishing this. I submit that the criterion for key word systems is an adequate summary of what a researcher who is now a staffer sees as important in data dissemination.

AGRICULTURAL COMPUTING AND LIBRARIES

by

STEPHEN M. WELCH

INTRODUCTION

I appreciate the opportunity to speak about agricultural computing and its interactions with a variety of information services including, in particular, libraries. I am going to start with a review of agricultural computing. This is a very dynamic and rapidly evolving area and a general perspective is helpful. Next I shall focus on certain information science aspects of the field. There are some unique types of data to be dealt with in agricultural computing and this has an impact on the organization of delivery systems. The final topic will be libraries and library science roles in agricultural computing. I shall discuss some clear needs that libraries are particularly suited to address.

AGRICULTURAL COMPUTING

One can subdivide the field of agricultural computing into four areas: on-farm activities, Extension Service programs, teaching efforts, and research projects. The on-farm area is rapidly developing at the present time and will probably be the most important sector in the future. There are a variety of functions that computers (especially microcomputers) can serve on the farm. These include record keeping, analysis, production decision aids, and on-line control.[1] Using microcomputers, one can automate many of the financial and production record keeping aspects of farming, thus eliminating a great deal of drudgery. Once the records are available in machine readable form, the micro can be used to provide detailed summaries and analyses. The speed of the computer allows the farmer to probe the data more deeply than would be possible were he limited to manual methods of calculation. This leads to a better understanding of the farmer's current situation and enables him to incorporate more detail into the management of his operations.

Another important use of computers is as a production decision aid. Computers can help the farmer make those critical, difficult, management decisions in a timely fashion. For example, a number of computer based models exist which integrate weather data, field scouting reports, and other information to produce recommendations for irrigation scheduling, pest control, planting, harvesting, etc. By using such software the farmer can exercise much more precise control over his production unit.

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Another area, which is just now beginning to blossom, is on-line control of the production process. On-line control incorporates automated feedback loops to operate farm devices in an adaptable fashion. For example, one can equip an animal shelter with sensors to monitor ambient temperature and humidity. Through electronic connections, the measurements can be fed into a microcomputer where sophisticated programs analyze them with respect to animal metabolism. The programs respond by controlling the venting or heating elements to maintain an optimal (i.e., weight gain maximizing) animal environment. Many other processes (e.g., irrigation, animal feeding, etc.) can also benefit from on-line programs.

The next major category of computer use is Extension agricultural computing. A number of states, over the past six to eight years, have instituted computer based systems for enhancing Extension operations. These are usually termed "computerized information delivery systems." Such systems generally consist of a large, mainframe computer connected via communication links to terminals in county Extension offices or, in some cases, belonging to end-users.[2] A number of information programs, production decision aids, and other types of software reside on the mainframe computer which can help users in their daily operations.

A recent innovation in Extension agricultural computing is the use of microcomputers in county offices to enhance the computing power available locally. This facilitates a number of other services beyond the types mentioned already. These include word processing, mailing lists, various computer-aided training activities, maintenance of client records, etc. Most of these functions fall under the general heading of office automation which is a highly active area in the computer industry at the present time. Usually, the county office microcomputers can communicate with the central mainframe machine. This permits the running of programs involving large amounts of file storage or calculation with the results being instantly reported back to the county.

One example of a computerized information delivery system is the AGNET system housed at the University of Nebraska and serving people in virtually every state of the Union.[3] Indeed, a few states have developed such a close working relationship with AGNET that they have become full AGNET partners. AGNET offerings include general information, communications facilities, and management models (i.e., production decision aids). AGNET serves users on farms and ranches and also in government, education, and industry. Over the years the use of AGNET has increased in an almost exponential fashion. From its beginning in 1975 when the annual use was a few thousand customer-hours, volume has risen to nearly 80,000 customer-hours in 1981. This represents a very large number of individual program accesses since AGNET sessions are relatively short.

Turning to instructional uses, a number of universities have organized microcomputer based agricultural teaching laboratories. Generally, such a laboratory will contain 20 to 40 microcomputers. Often they will be hooked together into a network also incorporating shared common resources such as

hardcopy printers and mass storage devices to hold student programs and other materials. Students study a variety of topics in these teaching labs. First of all, they learn about the microcomputers themselves to gain a familiarity with the technology. Beyond this, they are exposed to many of the same decision aids that they will use when they move into their chosen profession. In addition, they may also investigate older more traditional subjects but in a new more interactive manner which enhances the learning process. With the low cost of microcomputers, particularly when purchased in quantity, this type of teaching is going to become more common.

Finally, the last area of agricultural computing to be discussed is research. Agricultural research (like other biological sciences) is very expensive when measured in terms of dollars per data point. For example, a typical year-long research project may generate only a few hundred to a thousand data points and yet cost $5-20,000 to operate. This yields a cost per data point of, perhaps, $10 to $20. By replacing traditional manual methods of biological field research with more automated approaches, one can often reduce selected cost components by a factor of 10. At the present time, there are over 2,000 makes of instruments (representing almost every conceivable type) which can be directly hooked to microcomputers. These systems can record data on demand, at preset intervals, or in response to complex criteria, store the data, and perform statistical analyses completely automatically. As researchers become familiar with this technology and utilize it, they will realize long-term cost reductions that will prove very beneficial in times when agricultural research budgets are being reduced.

INFORMATION SCIENCE ASPECTS

In this section I will briefly review some of the information science aspects of agricultural computing. This is important because the characteristics of the information in a field often strongly influence the type of organizational or institutional methods used to handle that information. There is an hierarchy of information types of relevance to agricultural computing. In the bottom level are the numerous databases that are used to monitor weather, pests, soils, markets, crops, and other important features of the agroecosystem. These databases have a number of important characteristics. First of all, they are generally non-bibliographic databases. Instead, they contain numeric or scientific data related to specific agrobiological parameters. Also, these databases have strong geographic components. Conditions vary, of course, as one moves from one state (or even from one country) to the next ad the databases reflect this.

A third important characteristic is the database update rate. Agricultural databases have a wide range of update frequencies. Some databases are updated on an hourly basis such as the databases used to "nowcast" weather.[4] Using this information one is able to track weather events on a county to county basis and construct hour-by-hour schedules for many types

of activities such as combining, aerial applications, etc. Data moves from sensors to users in a few tens of minutes. Such information is termed "real-time data." At the other end of the spectrum are data types that may only change on a yearly basis. An example is yield summaries which are generated only at the end of each season.

At the next level above these databases are the basic processing elements that manipulate the fundamental information. These include computers, programs, communications channels, etc. There is, of course, a large body of technological information (mostly in established periodicals) concerning each of these particular elements. This knowledge base is growing as fast as the computer industry itself.

Of course, the update frequencies of the underlying databases have a strong influence on the types and organization of these second-level components. For example, only on-line systems can provide timely access to material that is updated on an hourly basis. At the other end of the spectrum are traditional publication methods that can be used to disseminate slowly cycling information. An example would be the Agricultural Statistics publications that each state compiles on an annual basis. If not used as part of some larger system, it is difficult to justify electronic media for such material.

The field of agricultural computing has now been around long enough for there to be a growing body of literature aimed specifically at the ag-computing practitioner. Farm periodicals, for example, are beginning to publish agricultural computing articles. In addition, there are a number of new periodicals dealing specifically with agricultural computing. These include full-fledged journals, magazines, news sheets, etc. and they come from a variety of public and private sources.

Separate from all of the above types of primary information are a range of what might be called locator tools usch as indicies, evaluations, bibliographies, etc. At present, there is a great dearth of such locator tools in agricultural computing. As a result it is very difficult for practitioners to find their way through the current morass of relevant information. The generation of these tools is certainly one activity where libraries have an important role to play. This is a task that is a traditional one for libraries and a number are beginning to compile agricultural computing materials.

LIBRARY ROLES

This brings us to a consideration of libraries and library science roles in the field of agricultural computing. In terms of indexing and retrieval services, I have already mentioned new periodicals, but this is certainly not the only type of entity that we need to keep track of. For example, we are experiencing proliferation of on-line services. I used to know, for example, how many states supported on-line computerized extension delivery systems; I don't any longer in spite of diligent efforts to keep current.

Of course, such on-line services are only one of several forms of electronic media. There are, for example, several hundred electronic bulletin boards in the country. These are free, interactive, computer based information sources used to exchange information on a wide range of topics including much more than just agriculture.[5] There are computer conferencing systems on which agricultural researchers, teachers, and Extension personnel can converse and engage in cooperative efforts even though separated by great distances.[6] We need to know where these services are, what their characteristics are, and how to access them.

Another confusing area is hardware itself. New equipment is appearing on a daily basis. Unless one follows a large number of individual trade journals it is difficult to know what is available. Even more crucial are the kinds of equipment that can be assembled together into compatible systems serving agricultural needs. Along with this are price considerations. Speaking only half facetiously, price information may well have to be one of the hourly-update databases mentioned previously. And, of course, there is a growing body of literature on all of these topics that requires indexing and dissemination.

In terms of software and database information, we have very few methods at the present time for determining what programs even exist. There have been a number of surveys but listings can change very rapidly. Moving beyond mere existence, what are the algorithms or solution methods that these programs use? What databases are available and what are their characteristics? And, most important, where can we find evaluation information on all of these subjects?

Libraries have an important role to play in the collection of these types of information. I think that there are perhaps two ways that this might occur. First of all, some of these efforts may be (and are being) organized as special programs within existing libraries such as the National Agricultural Library. On the other hand, the agricultural computing community is also recognizing the need for special institutions to act as clearinghouses for this kind of information. Such clearinghouses will, themselves, be creating and maintaining libraries as part of their activities.

An example of such an institution is the North Central Computer Institute (NCCI) which is headquartered at the University of Wisconsin in Madison.[7] The NCCI is an association of the land-grant universities in the 12 north central states. The goals of the Institute are to enhance the agricultural and rural development computing efforts of its member states. The NCCI is funded for a five-year period by the Kellogg Foundation and the north central agricultural deans and directors. The NCCI constitutes one of a projected series of regional programs about which the next speaker, Dr. Kramer, will make some further remarks.

As part of its activity, the NCCI maintains a library containing a wide variety of computing literature ranging from the purely technical to other materials specific to agricultural computing. Beyond this, the Institute takes an active role in the generation of new software and databases. For example, the Institute participates in and partially funds projects devoted to developing software of regional application. These new programs are then published through the NCCI Software Series, a peer-reviewed journal of software. In addition to this, the Institute maintains an on-line keyword indexed database of software containing summary information about software functions, hardware requirements, contact persons, and availability.

With further developments in agricultural computing, I think we can expect to see an increase in these activities. As this happens, it is important that libraries be active participants. For example, libraries should not simply index or summarize the new technology; libraries should actively exploit that technology for the display and dissemination of their materials. Libraries should be innovators. At the present time, for instance, libraries make use of on-line retrieval services. Libraries, however, need to move beyond this and become involved with microcomputers. Libraries need to enhance their services with new display technologies such as computer graphics. I believe that computer graphics is the single greatest revolution in information handling since the invention of the computer itself.

As an example, consider the previously mentioned problem of generating compatible hardware designs. Given the wide variety of hardware and software available on the market today, it is very difficult for the agricultural computing practitioner to select a set of components which, together, will accomplish a particular task. I believe that there is a need for a nationally-available information service which could keep tabs on this proliferating technology. By interacting with clients through inexpensive graphics terminals, this service would create displays of configurations that would meet given design objectives.

When the user first logged on such a system he or she would see a display showing a generalized microcomputer system. Through graphic edits the user would inform the service what specific equipment was already on hand. By responding to menus the user would then indicate the types of additional information desired. Often this would be a request for equipment (compatible with the existing configuration) needed to accomplish some specific function. The service would generate lists of such devices and, on request, draw block diagrams of the resulting systems. Standard, bibliographic searches could also retrieve literature information on system performance and user evaluations. Through an iterative process the user would gradually work out an equipment configuration that would meet his or her needs.

Needless to say, this last paragraph is a bit speculative. To the best of my knowledge, there is nothing like it at the present time although there is an obvious need for it. Such a system, however, is not beyond the founds of current technology. For example, on-line databases used in chemistry already employ a certain amount of graphics to portray chemical structure information. The display of hardware configurations is not such a dramatic departure from this as to be inconceivable. By using terminals and cheap telecommunication lines, much hardware information (even slow-scan video photographs) could be disseminated through libraries to a wide audience.

SUMMARY

In summary, agriculture, like the rest of society, is undergoing an information explosion. Computers are the leading edge of that explosion. While, in the long run, computers will permit better management on the farm, in the short run, the profusion of technology is often more confusing than helpful. Libraries, whether public, private, or other, have always been key elements in the organization of information. There is no reason to suspect that they will not continue in this role with respect to the emerging field of agricultural computing. Beyond this, the opportunity exists for libraries to utilize this same technology to generate even newer and more innovative forms of information presentation for their clientele in the future.

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FUTURE OF COMPUTERS IN AMERICAN AGRICULTURE AND THE RELATIONSHIP TO LIBRARIES

by

ROBERT C. KRAMER

I spent the week of June 8, 1980, in the Washington, D.C. area visiting USDA agencies, including the National Agricultural Library. The purpose of my visit was to learn about the use of computers, computer networks, and computer services. It was an enjoyable and informative week and each person with whom I visited was most helpful. When I was invited to participate in this Symposium, I recalled my 1980 visit and readily accepted. I look forward to a discussion following my remarks.

I shall review the history of computer developments, computer uses in American agriculture, grants made by the Kellogg Foundation, future uses of computers in agriculture, and relationships to libraries. Most historians will agree that two decades comprise a very short time period. Computers, however, have been used to assist American farmers for only 20 years. The maxi or mainframe digital computers were used first, in the early 1960's, to analyze agricultural problems. Dairy Herd Improvement Associations began computer programs to provide herd data to dairy farmers. Land-grant universities started computerized farm accounting projects. In the late 1960's, mini-computers became available. They were used for agricultural research and there were terminals in the field. Microcomputers and programmable calculators were developed in the mid 1970's.

In the late 1970's the first programs for the micros and hand-held programmables were written, mostly by professors and Extension specialists in Colleges of Agriculture. Micros were placed in county offices of the Extension Service and other USDA agencies. Electronic mail programs began. Other special applications of micros were developed. Around 1980 the Green Thumb and Video-Text programs were started. We are living in a microcomputer revolution with continuing hardware cost reductions and increasing quantities of software. One of the big challenges is to keep informed about recent developments in the information and computer field. This Symposium will surely help.

The W. K. Kellogg Foundation's interest in the utilization of computers has covered our three programming fields -- agriculture, education, and health. Several higher educational institutions and academic health centers have received grants so that computer applications could be utilized to improve the educational and health delivery processes. Twenty years ago the Kellogg Foundation provided a grant to Michigan State University to start a computer program which is called TELFARM. A few years after TELFARM began operating, the Kellogg Foundation provided another grant to Michigan State University to start the program called TELPLAN. Six years ago the Kellogg Foundation provided monies to Purdue University to start the Indiana state system called FACTS.

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USE OF COMPUTERS IN AGRICULTURE

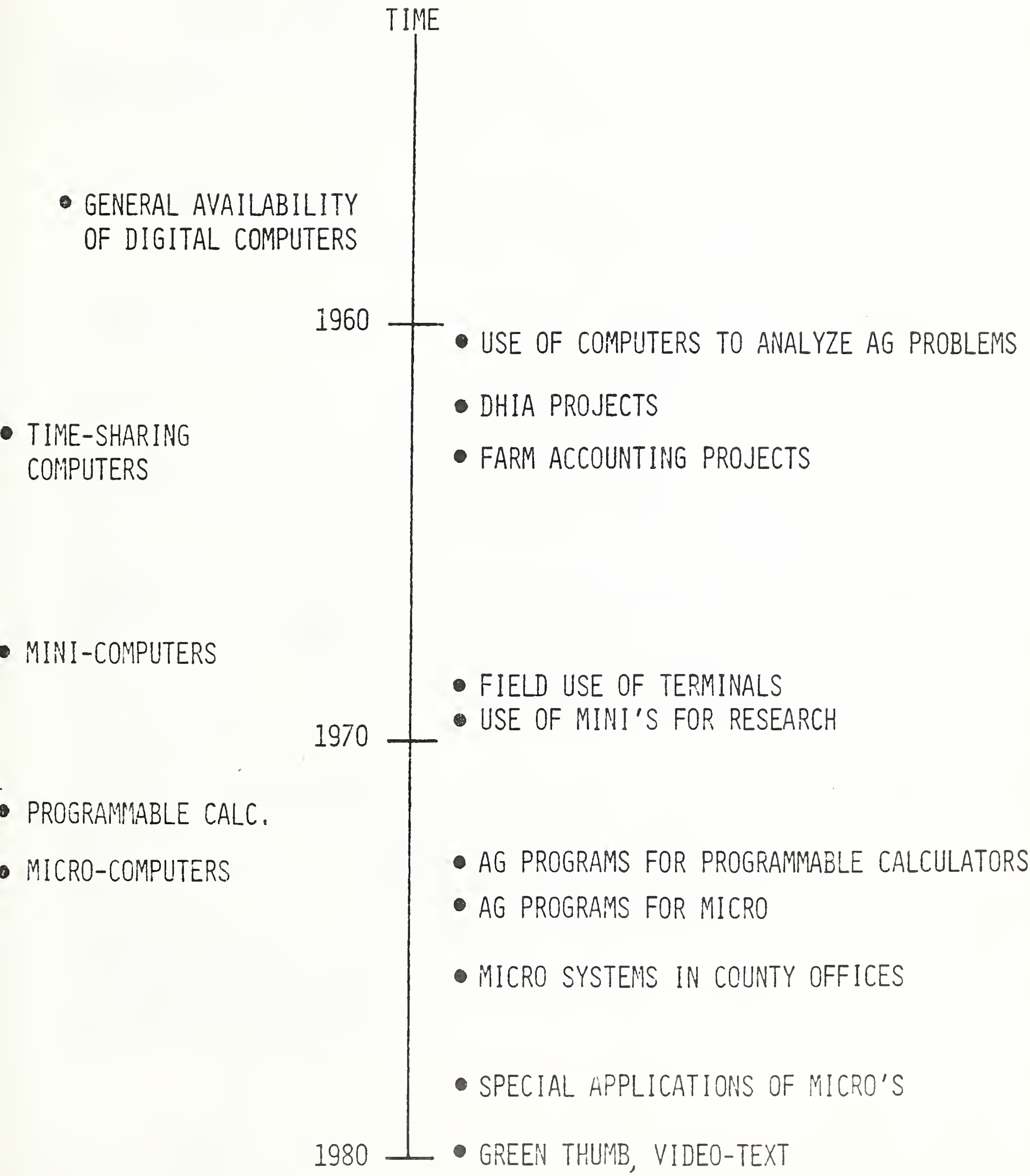

FIGURE 1. TIME CHART

In the past two years the Kellogg Foundation has funded the following state projects:

RECIPIENT	PURPOSE	PROJECT DIRECTOR
Michigan State U.	Maximize animal production by computer evaluation of cost benefits of animal health care	Dr. Edward Mather, Chairman Dept. Large Animal Surgery
U. of Florida	Establish a computerized agricultural diagnosis, consultation, and management system and computerized crop and pest control	Dr. F. A. Johnson, Assoc. Prof. and Extension Entomologist
Cornell U.	Develop a computerized program to improve the transfer of agricultural technology to New York dairy farmers	Dr. Wayne A. Knoblauch, Dept. of Economics
U. of Illinois	Assist Illinois farmers to use mini and microcomputer technology to improve their farming operations	Dr. Delmar F. Wilken, Prof. of Farm Management
Clemson U.	Improve the transfer of agricultural technology to agricultural producers in South Carolina by installing microcomputers on campus and promoting their usage statewide	Dr. W. A. Tinsley, Dept. of Ag. Economics and Rural Sociology
Calif. State U., Chico	Enable faculty members and professional staff of NOWCASTING, a specialized computer weather forecasting service, to assist Sacramento Valley ranchers in improving farming operations	Dr. Rolland K. Hauser, NOWCASTING
Purdue U.	Indiana Farmer Survey	Dr. Howard G. Diesslin, Director, Indiana Cooperative Extension Service

U. of California	Enable agricultural economics faculty to convert a large computer-cost-of-production program into a software package for microcomputers	Dr. Gordon Rowe, U. of Calif., Berkeley
Penn. State U.	Northeast region computer feasibility study	Dr. G. Art Hussey, Jr., State Leadership Computer Services
U. of Arizona	Western region computer feasibility study	Dr. Roy Rauschkolb, Dir. of Cooperative Extension
U. of Arkansas	Beef evaluation	Dr. Hayden Brown, Jr., Professor, Dept. of Animal Sciences

In the past three years I have had an opportunity to meet with all of the directors or associate directors of the Cooperative Extension Services in the United States. I have also had an opportunity to meet with Agricultural Experiment Station Directors, Extension specialists, and faculty members in agriculture from many states in this nation. They report that farmers are increasingly using computers and the computer networks which are operated by the University of Nebraska, Michigan State University, and Virginia Tech. These networks are called AGNET, TELPLAN, and CMN. Extension agents are using terminals to access university main frame computers via these networks. A few farmers are using terminals to access large computers which are owned by universities or private companies. Farmers are buying their own small computers--both the micro and minicomputers are included in the definition "small." Feed companies, farm management associations, banks, and governmental agencies such as the Farmers Home Administration are also increasing the use of computers and providing farmers with computer information.

In a recent survey of Indiana's farmers, 13 percent of the 354 respondents presently own an on-farm computer. The growth rate of on-farm computers in this sample group is accelerating each year. In 1979 the number of computers increased two percent, in 1980 it grew three percent, in 1981 seven percent of the group bought their own system. The projection for 1982 is 10 percent, and it is possible that 24 percent of the sample will have their own system by the end of the year. Since there are 87,000 farms in Indiana, the potential number of on-farm computers during the next few years is in the tens of thousands. If this sample is representative of what is occurring in other states, and if the growth trend continues, there could be over one million computers in use on farms by 1985.

Three-fourths of all of the mid-size farmers in the United States in 1990 will utilize computer software in helping make management decisions on their farms. A large proportion of the mid-size farms--farms that have gross farm sales ranging between $20,000 and $150,000 per year--will utilize their own computers. They will store their individual farm information in their computers and will have access to larger computers which can download data and programs into their on-farm systems. Many of the farming operations will be computerized and controlled by electronic instrumentation, thereby automating many standard tasks.

There will be intelligent computer terminals in 90 percent of the county extension offices in the United States. There will be communications between farm offices and county extension offices by telephone, by FM signals, or by hard wire. Virtually all of the Departments in the Colleges of Agriculture and Home Economics will have intelligent terminals and/or small computers. On-campus interdisciplinary cooperation will increase significantly in the decade of the 1980's. Subject matter specialists and researchers will cooperate in developing software that can be utilized by extension professionals and farmers to help agricultural producers with decision-making. Academic personnel policies will be modified so that specialists and researchers will be given credit for their contributions to computer applications. Credit will be given for the development of computer programs and credit will be given for the development of educational and decision-making tools which will be utilized by agricultural producers.

Agriculture probably has the honor of being the top industry in the United States where the end-users (farmers) know more about computer programs and utilize computers more frequently than their counterparts in other industries. In 1990, the gap will widen and even more end-users in agriculture will be sophisticated and will be using advanced computer technologies. Computer marketing or electronic marketing will be commonplace in 1990. Many of the marketing decisions for agricultural products will be made at the farm, farmer co-op, or county level utilizing sophisticated computer marketing techniques.

There will be knowledgeable and active computer committees on each of the land-grant university campuses. These computer committees will have a definite role and will provide the latest information so that the land-grant university can provide timely and usable information to their clientele for decision-making.

In each of the four geographic regions of the United States there will be agricultural computer centers or institutes. There is one in the North Central Region and the Kellogg Foundation is providing 50 percent of the funding. These centers or institutes will help with the development of regional programs, maintain an up-to-date inventory of software, help with the standardization of computer languages, develop methods whereby computer equipment manufactured by several different companies can be interlinked via electronic communications, and advise interested campus administrators on

how to have a cost-effective computer system in each of the states. They will be linked together and each also will be linked to national computer centers.

Regional sharing of software, regional sharing of specialists, and regional computer networking will be commonplace in 1990. Regional committees will work with the USDA, farm organizations, agricultural banks, agricultural cooperatives, and private agri-businesses in the sharing of data and data bases which will be used by commercial farmers in each of the regions. At the national level, the U.S. Department of Agriculture will have effective computer committees that will span the different parts of the U.S. Department of Agriculture and will also tie to the Department of Commerce, Department of Labor, Department of Education, and other governmental agencies.

In the action agencies of the U.S. Department of Agriculture, there will be coordination among the different programs that are developed for computers so that American farmers can be better served. In the other USDA agencies (ESS, FAS, FCS, etc.), there will be a coordinated development of computer software. These programs will be placed on an on-line, interactive, information retrieval service. OASIS is on-line now. Individual state specialists, researchers, and administrators will be able to access the on-line service and get the latest market information as well as the latest statistics and publications on United States and world agriculture. The Situation and Outlook Board will release its lock-up reports to an on-line interactive information retrieval service and, 10 or 15 minutes after the reports are released, this information will be available to all those who have made the necessary preparations to access this information. Two years ago I predicted that this would happen and I am glad that it has.

There will be a national inventory of agricultural software which will be developed with the assistance of specialists and faculty members in each state, regional computer institutes, and a national computer committee. This national inventory of agricultural software will be on an on-line, interactive, information retrieval service. By using TYMNET, TELENET, or other national networks, an inquirer can learn quickly what programs are available and for which hardware they are written.

There will be a national computer policy committee which will be effective in making recommendations about effectively using computers to assist agricultural producers and agribusinesses. There will be a national computer center located either on one of the land-grant university campuses or in an off-campus location. In this national computer center will be the latest hardware, expertise, and training programs so that agents, specialists, researchers, and administrators in the USDA and land-grant systems can learn about computers and their agricultural applications.

WKKF LIBRARY PROGRAMS

Earlier I mentioned the Kellogg Foundation's grants to institutions of higher education. I gave examples of grants for agricultural applications to universities. I turn now to our support for libraries.

Improvement of libraries as a continuing Foundation concern dates from the Michigan Community Health Project. Between 1938 and 1943 support for libraries in the seven demonstration counties totalled over $400,000 for education of library staffs and provision for consultants and books, including the notable Five for One Book Program which modernized many book collections. Of wider scope was later support of an education program for library trustees (Michigan Department of Education, 1945-47) and establishment of a baccalaureate curriculum in library science at Western Michigan University (1945-49); it is now a graduate program accredited by the American Library Association. Since 1962 over $8 million has been provided in behalf of four major national library programs and for a major Michigan library improvement initiative.

Library support on a national scale began in 1962 with the program Library Books for Teacher Preparation. Grants of $10,000 were made to each of 251 small independent liberal arts colleges to purchase books in support of their teacher training curricula. Three years later the 33 colleges of the United Negro College Fund received grants for library improvement--$15,000 each to 16 colleges not included in the 1962 program, and $5,000 supplements for 17 which had originally participated. In 1971, as concern for the environment became widespread, the national program College Resources for Environmental Studies was approved. Professional consultants agreed that $5,000 sufficed for an undergraduate collection; that amount was awarded to 299 small independent liberal arts colleges. Thus, the first three national programs focused on enlargement of library collections.

During the 1970's, two major changes in the American library scene affected colleges:

-- federal aid provided annual direct grants to academic libraries for the purchase of materials (Title II-A, Higher Education Act) and one-time grants for special projects;

-- development of machine-readable cataloging (the MARC program of the Library of Congress, inaugurated by private funding) enabled wide expansion of cooperative cataloging, and computer printing of catalog-ready cards.

The need for additional books was lessened and the way was prepared for an attack on the cost of technical services, as contrasted with direct service to students. The Foundation, therefore, designed the National Library Demonstration Program of 1976 to enable 300 small college libraries across the country to join the national network of the Ohio College Library Center (now OCLC, Inc.) for the advantages of reduced cataloging costs and speedier

interlibrary loans, among many other provisions. Grants were accepted by 268 colleges. This program led also the Michigan Library Network.

In 1976, when planning was under way for the latest national college library program, Michigan presented a special situation. Several years earlier, under a WKKF grant for faculty development, the librarians of the Association of Independent Colleges and Universities of Michigan (AICUM) held a workshop at Adrian College to plan cooperative efforts for library development. A visit to OCLC at Columbus was approved by AICUM, following which the librarians of Adrian and Kalamazoo colleges headed an ad hoc organization which eventually became the Michigan Library Consortium (MLC). To secure economical access to OCLC it was necessary to recruit larger libraries, a goal attained after state-wide meetings at the Kellogg Center with additional leadership from Michigan State University and the University of Michigan. MLC was formed specifically to channel OCLC services. Its membership in 1976 was about 35, composed primarily of academic libraries, with a few from the public sector. It requested support from the Foundation to become operational.

Simultaneously the Foundation investigated the possible utility of OCLC to public libraries. In Michigan that State Library Services (SLS) had, with federal and state support, organized the majority of public libraries into 24 regional systems. Since 1976 the regional systems have been reorganized into somewhat fewer regional cooperatives. Willard Library in Battle Creek is an example: it serves the other public libraries of Calhoun, Branch, and Hillsdale Counties in book ordering and cataloging, inter-library loan, and securing materials from the State Library. Like other system centers, Willard Library is linked to SLS by Telefax and WATS lines, over which it daily relays requests for books, periodical articles, and subject information not available within the systems. SLS fills such requests from its collection or by borrowing from Michigan's research libraries.

The existence of the two somewhat parallel systems, the public network centering on SLS and the academic network (in embryo) of MLC, led to a series of meetings among librarians who were almost strangers to each other. With the feasibility established, the Foundation embarked on a series of grants to every college, university, and public library in Michigan.

Public library systems received $8,000 each, as did the large public libraries; mid-size public libraries received $1,000 each, and small public libraries received $700. The $8,000 grants paid for OCLC terminal installation or for participation in a processing center which used compatible cataloging from other sources; this latter is practical for many public libraries circulating multiple copies of popular books. Smaller grants were allotted for attendance at workshops and participation in public library systems. Academic libraries and library schools received $7,000 to $7,700 each for OCLC memberships; four which shared terminals received $4,000 each.

The extent of support for libraries by the Foundation is greater than may be inferred. Compiled from the historical data retrieval system, the following table summarizes many individual grants. The major programs, listed by name, were supplemented by others which appear under geographic totals.

Expenditures on Library Programs

Michigan Community Health Project	$ 405,092
Battle Creek Projects	681,816
Other Michigan projects	301,539
Latin American projects	1,217,248
Library Books for Teacher Preparation	2,500,000
United Negro College Fund	325,000
Environmental Library Resources	1,500,000
National Library Demonstration Program	2,100,000
Michigan Library Network	1,190,645
OCLC grant related to the two above	315,000
	$10,537,150

Summary

I have reviewed the Final Report to Secretary Block, "Assessment of the National Agricultural Library," prepared by the Interagency Panel on the National Agricultural Library." It is an excellent report. The Panel says, "A national agricultural library, using the most advanced computer and communications technologies, is a cost-effective and necessary instrument in promoting access to, and use of, information in agriculture and allied sciences for public and private sectors alike." We at the Kellogg Foundation agree and are providing grants to assist in developing and delivering software to be used by farmers, ranchers, and agribusinesses in the United States. During the past two years I have seen real progress in the USDA in using advanced computer and communications technologies. There is evidence of more cooperation and coordination. I wish the USDA and NAL well in the future.

STALKING THE SPECTOR OF HUNGER

by

JOHN S. McKELVEY, JR.

INTRODUCTION

Many are the ways one can stalk the specter of hunger. I plan to spend my time (and yours) tonight in singling out several of these ways and in pointing out the complexity of succeeding in allaying hunger throughout the world. I shall deal with plant and animal production, protection against insects and diseases, and implementation of advances in production and protection.

AWAKENING

Before one begins to bear down on hunger in a comprehensive way, however, he really should experience hunger himself to know what a miserable beast that specter can be. I cannot pluck your heartstrings with a personal saga of rags to riches of the Horatio Alger sort because I came from a well-to-do family living in New York City where my father practiced law. For my mother, brother, sister, and me he provided a farm upstate where we would go during the summer months and, there, we experienced no hunger until the year my sister got married. My parents then staged such a sumptuous wedding in June for her that literally not a penny was left in the family coffers to purchase food during the month of July. In response to the queries from my brother and me, "What is there to eat," I recall vividly my mother asking, "Can't you find some vegetables in the garden?" The Garden? That weed patch? It never occurred to us until then that a garden was meant for survival. We looked upon a garden as a necessary evil; a place for disciplining unruly boys who had priorities other than weeding. All we could find in that garden were leftover radishes--deformed, tough, and mealy--secondhand snap beans which the Mexican bean beetle had reached first, and carrot roots, more arty than tasty, entwined as they were with roots of weeds. We were hungry!

My next bout with hunger came in graduate school at Virginia Polytechnic Institute (VPI) in the early 1940's. Then I was on my own earning the princely sum of $30 per month as an assistant in plant pathology, enough to pay board and room if board consisted of two meals a day only. My companions and I would get ravenous in late evenings and would drop by the university's snack bar on the way home from the laboratory. I would purchase a package of chocolate cup cakes, two to a package, the most that I could afford. They helped some. Inadvertently, one day I read the fine print, the list of ingredients, on one of those packages and prominent among them was agar. I couldn't believe it; the same tasteless non-nutritious compound upon which I was growing my fungi. The wrapping sparked my interest in reading fine print more than the cup cakes assuaged my hunger.

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As you can see now, the specter of hunger then passed me by for other victims and, in truth, I would have difficulty remembering true pangs of hunger since graduate school days. But one thing led to another, notably Dr. J. G. Harrar, my professor of Plant Pathology at VPI joined the Rockefeller Foundation to lead their program in Mexico to help that country become self-sufficient in basic food crop production and he invited me to join his team to help alleviate the hunger of others in a massive way.

PRODUCTION

The trustees of the Foundation realized that the remarkable advances to which they had been party in the golden age of parasitology--the turn of the 20th century--not only led to the control of malaria and of yellow fever, among other tropical diseases, but also unleashed that specter of hunger by enabling whole populations to experience long life spans and reduced infant mortality. Thus, the way was paved for burgeoning populations to crash their food supply barrier. When the opportunity arose through invitation from the Mexican government for the Foundation to cooperate in enabling Mexico to become self-sufficient in the production of corn, beans, and wheat, the Foundation accepted. Nobel Prize winner E. Borlaug's improved varieties of wheat became a beacon of success followed by corn and beans. Beans carried a heavy pest load--root rots, virus diseases, and insects--that never would allow those plants to attain their full yielding potential. Nevertheless, our program produced varieties resistant to these pests, varieties that we could disseminate. We roamed Mexico to peddle those varieties of beans. We tried to convince farmers in the chronically drought stricken states of Aquascalientes, Zacatecas, and Durango to grow small seeded black beans from Vera Cruz in place of their big seeded Bayo Gordo tan beans in which they had confidence. The black beans yielded better than did the Bayo Gordos. Alas, we were asking the impossible of those farmers who lived in a sun-drenched area which left them too poor to take chances. Three good rains per season was the most they could hope for. I sat in the homestead of one family on the only chair they possessed in the midst of flies and the heat-eating "visnagaras"--candied cactus blossoms--while the matron of the family exulted over the fact that the first rain had been good and should others follow she might, just might, be able to afford a new dress--the first in many years. There I saw an inkling of the nagging problem of tradition standing in the way of improvement in food crop production, one that would plague us throughout our efforts for the next 30 years.

The Mexican agricultural program laid the groundwork for producing the so-called miracle wheats which helped India, Pakistan, and Turkey become self-sufficient in wheat production. It led to the creation of IRRI (International Rice Research Institute) which produced varities of rice that likewise helped the countries of Asia meet demanding food needs. It spawned the whole network of international institutions now 11 in number with a comprehensive budget of well over $150 million a year for research in the developing world. Finally, in a personal vein, it projected me into the New York offices of the Foundation as a talent scout for bright young

agricultural scientists in Latin America who might need additional training in agriculture or in veterinary sciences. It removed me from the immediate purpose at hand, to conquer hunger directly, but put me close to the longer-term objectives of stalking that apparition of hunger by upgrading faculties of agriculture and of veterinary science throughout Latin America. These faculties would, in turn, furnish the expertise for future generations to cope with food shortages and hunger.

In this assignment, travels to the far reaches of many--nearly all--Latin countries, and through the United States as well, taught me that the family farm was indeed an inviolable institution and that it would remain so. Any perceptive individual could readily discern the linkages between agricultural pursuits and the lives of the people engaged in them; for instance, one need only travel through New York State to see the influence of the Dutch in the dairy industry and the forage crops grown there. One also could easily compare wheat farming in the Scandinavian countries with the Scandinavian settlements in Minnesota and Wisconsin and other states of the midwest where wheat dominates as a crop. One could see, in California, Japanese settlements specializing in intensive vegetable crop husbandry. Abroad, in Brazil, one could also witness the vestiges of the plantation agriculture of the southern states in the small town of Americana where disgruntled southerners from the United States settled following the Civil War. In Africa, if one wants to produce rice, he invites the Chinese to develop rice paddies as they have already done in Sierra Leone, in Uganda, and in other countries where that Asian expertise may be needed.

As I gained acquaintance with those rugged weather-beaten descendants of the Incas in the Andean region of Peru, I began to realize that their agriculture based on corn and potatoes consisted of no narrow technical discipline. It permeated their social, cultural, and religious life--the ruins of Macchu Picchu told me so--and an agriculture so ingrained in the lives of the people seemed well-nigh immutable come feast or famine.

PESTILENCE AND DISEASE

In the Conquest of Hunger Program of the Rockefeller Foundation, we began to focus on one of the most debilitating diseases of mankind--of livestock as well--trypanosomiasis, which the tsetse flies of Africa transmit. Here was a disease agent, the trypanosomes, which once in the human body or in livestock commanded priority of nutrition. It sapped its host of strength, brought on anemia, then went beyond the destruction of red blood cells to attack the cerebro-spinal fluid to cause coma and death. It left its victims with a voracious appetite for meat to replace stolen protein and sent them to the market places to purchase minerals or forced them to geophagy--earth eating. Could we, can we, devise a vaccine to immunize man and beast against the trypanosomes--the disease agents of trypanosomiasis? They are foxy--they change their antigenic surface coats readily and thus thwart such efforts; we have yet to answer that question positively but until we do the humid tropics of Africa may continue to lie barren of livestock and the people may be ever under the threat of contracting sleeping sickness.

In the damage they cause, pests and diseases do not distinguish among old, new, and third worlds. Some, as international travelers, became typical tropical tramps which accompany the world's most effective disseminators of pests and diseases--human beings. In the main, the technology for coping with pests in the United States serves equally well in the developing countries, but for different reasons. Here we search for alternatives to pesticides to alleviate noxious effects of hardline persistent chemicals in destroying our environment, chemicals which up to now we have been able to afford. There we seek alternatives to pesticides to bring the cost of insect control within reach of the peasant farmer. In both cases we rely on the following: modern advances in the resistance of plants to insects and plant diseases; the use of insect pheromones (perfumes) to upset mating schedules and, therefore, lower reproductive potential; sterile insect release methods (SIRM) to apply the coup de grace to descending pest populations, and a thorough knowledge of what happens to disease agents, such as trypanosomes, when they have to confront membrane barriers in insects which one way or another they must circumvent or pass through.

Let no one delude himself into thinking that protein comes easily to the jungle-bound villages of the humid tropics of Africa. Indeed, the people of the hinterland in Zaire routinely derive from 30 to 40 percent of their protein from termites, grubs, and other insect life. Wild game is scarce; firearms are virtually non-existent. A feeble bow, a quiver, and a few wobbly arrows or a spear dipped in poison constitute hunting equipment. If an arrow hits its mark and pricks the skin of an animal, one still must spend days stalking the animal while the poison takes effect.

At Yangambi on the upper reaches of the River Zaire in Zaire (formerly the Congo River which Vachel Lindsay immortalized in his poem of the Congo, "Then I saw the Congo creeping through the black, cutting through the forest with a golden track"), the Rockefeller Foundation's Director of the Faculty of the Institute of Agriculture responded to an emergency call from one of his professors to take his wife, about to give birth to a child, to the clinic. He used his personal car because the ambulance was broken down. On the way to the clinic he ran over a scrawny pig--a sow--owned by a villager. Before he could wrest himself from the clutches of this and companion villagers, he had to pay $300 not only for the pig but also for her potential litters as well and even at that price had to let the local people keep the pig. Against such a shortage of animal protein what a vicious insidious specter that specter of hunger turns out to be.

IMPLEMENTATION

FOOD AND AGRICULTURAL POLICY

As we move through the 1980's we see the impact of the green revolution in the far east where rice is the staple and we see its impact in the middle east as well--in Pakistan and India where both rice and what are staples. In these areas of the world, not just the performance of improved varieties

of wheat and rice but effective agricultural policies as well enabled the countries of those regions to exploit the new technology and to divest themselves of massive imports of grain to feed their people. A look at Africa presents a different picture.

Sub-Saharan Africa needs help. It is the only region in the world where per capita food production has declined over the past two decades. Today, in most Sub-Saharan countries, per capital caloric intake is below minimum nutritional standards. Demand for food imports is increasing at a time when grain prices are rising and when many African governments have acute balance of payment and foreign exchange problems.[1]

Part of the problem of food deficits in Africa lies with the structure of demand. Demand for wheat and rice is high especially in urban areas. Wheat cannot be produced in many of the countries, while rice production is frequently more difficult and more costly than the production of less preferred crops, such as millet, sorghum, maize, pulses, roots and tubers.[1]

Much of the problem, however, centers around agricultural and food policies which do not provide incentives for peasant agriculturalists and others to produce. Technical impediments--lack of credit, of fertilizers, of pesticides, poor seed distribution, unavailability of machinery and lack of infrastructure--all stand in the way of agricultural development in most of the African countries south of the Sahara.

A plethora of multilateral and bilateral donor agencies are assisting African countries in tackling the problems of food production; most have met with minimal success. None, not even the international institutions as represented by the International Institute of Tropical Agriculture (IITA) in Nigeria, the International Livestock Centre for Africa (ILCA) in Ethiopia, or the International Laboratory for Research on Animal Diseases (ILRAD) in Kenya, has as yet made more than a dent in the complex set of problems that keep the African nations from enjoying a prosperous agriculture. This situation combined with the nagging plight of most of the African nations south of the Sahara unable to feed their own people--indeed to earn the foreign exchange their lands are capable of producing--challenges us to rethink our role in Africa vis-a-vis the production of food stuffs, the dissemination of research information upon which farmers can act, and the improvement of agricultural and food policy to make the agricultural systems of Africa work.

Food sufficiency and a prosperous agriculture rely heavily on the three vintage agricultural systems deeply ingrained in the culture of the African people. The first is an intrinsic African agriculture which embraces sorghum, millet, and cowpeas among other crops and to which in neolithic times the headwaters of the Niger River gave birth in what is today the Sahel; it has expanded from Sub-Saharan Africa in the west to the highlands

of east and southern Africa; barley and wheat from the highlands of Ethiopia infiltrated this system in prehistoric times; maize from the New World joined it recently. The second is an animal husbandry system embracing cattle, pigs, goats, and sheep which spread from Egypt across northern and western Africa in the 5th millenium B.C. and fed the nomadic people in ecological zones on the frayed edges of those which support sorghum and millet; this system now stands poised to advance in the humid tropics if the tsetse fly and the trypanosomiasis it carries will let it. The third system constituting the Malasian agricultural complex introduced yams, taros, and coconuts to Africa; it swept west across the continent from the Malagasy Republic about 500 B.C. to occupy the tropical forested area and it established a slash-burn farming system that replaced forest and hunting industries. Modern methods of no-till agriculture, herbicides, and other inputs are bound to alter it. Finally, crops from the New World, cassava, groundnuts, maize, tomatoes, snapbeans, during the past 400 years have come to overlay in salt and pepper fashion the traditional cropping patterns of the past. These crops now assume a role in agricultural production far beyond that of their original function--seasoning the systems that were extant.

The vintage systems of agricultural production will adjust to the runaway population explosion au courant in Africa, to the rash of urbanization as well and, ultimately, to a demand from other parts of the world for the agricultural bounty which African countries could produce. These forces will lift the face of African agriculture as it has been practiced in the past and is practiced today. We should be party to the kind of progress that ensues and to influence it to go in the best direction possible.

Twenty years of effort and expenditures on the part of the nations themselves with strong support from donors have built an impressive corps of trained personnel in most of the disciplines of agriculture. Although the body of trained personnel in agriculture for Africa falls far short of those for Latin America and for Asia, still it is remarkable in its development in Zaire, where the paucity of agricultural scientists is the greatest and, in 1959, could point to but one individual with master training in agricultural sciences. Today over 150 individuals have earned first degrees as engineers in agronomy, 50 have earned the M.S. degree, and from 20 to 30 have earned the Ph.D. degree. Lapses in program advancement still occur, however. Governments do not use effectively their human resources. High administrative posts undergo frequent change of personnel--capricious changes--which do not allow governments to sustain long-term courses of action that would benefit the people in terms of food production, distribution, and marketing.

Likewise, the vicious circle needs to be broken of qualified agricultural scientists who gravitate to high paying academic posts in order to educate other agricultural scientists to serve in high paying academic posts. Effective lobbies need to be formed from those representing the peasants

and from the private landholders which could assist their governments in developing sound agricultural policies. The details of these problems differ from country to country but such problems in themselves are generic and they are tractable. Fundamentally, agricultural prosperity must rest on improving the sorghum, millet, and maize culture of Africa, the livestock industry, the farming system's formulae for the humid tropics, and on strengthening the interrelationships amongst the farmers, academics, and government officials.

CONCLUSIONS

Clearly stalking the specter of hunger conjures no simple formula. Increases in crop production today are as essential as they were decades ago. We must exploit biotechnology, specifically genetic engineering, to achieve another quantum jump in plant production. Pestilence and diseases still take 25 to 30 percent of the crops and the food producing animals that we grow. We must seek new methods to cope with them. Education and training of young agricultural scientists must proceed apace. Some areas of the world seem to be better off today than they were 40 years ago in the alleviation of hunger. Others, such as the African continent, are not. There, as elsewhere, food and agricultural policy must improve and population growth rates of three to four percent will clearly have to abate if countries experiencing such explosive increases in population have the slightest hope of keeping the specter of hunger at bay.

At the dawn of the discovery of the New World, Dr. Monardes[2] from France stalked the eastern borders of the American continent in search of botanicals--medicinal plants--which he could take back to the Old World to help alleviate the suffering of his patients in Europe. He found some and recorded his findings in a book entitled "Joyfull Newes Out of the Newe Founde Worlde." Today, with our wealth of information and expertise in agriculture, would that we could transmit to the Third World nearly 500 years after Monardes' explorations not simply handouts of grain and other surplus foods, which, over the short-term, serve their purpose, not only solutions to the basic problems of crop production, freedom from pestilence and diseases, but also valid recommendations that governments will accept for appropriate policies enabling Third World populations to live an abundant life. Then, indeed, we would be reporting to them joyful news from the new found world.

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